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TITLE OF THESIS/*TITRE DE LA THÈSE* THE EFFECTS OF SOW NUTRITION DURING GESTATION ON THE BODY COMPOSITION AND SURVIVAL OF YOUNG PIGS

UNIVERSITY/*UNIVERSITÉ* UNIVERSITY OF ALBERTA

DEGREE FOR WHICH THESIS WAS PRESENTED/*GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE* Ph. D

YEAR THIS DEGREE CONFERRED/*ANNÉE D'OBTENTION DE CE GRADE* 1977

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THE EFFECTS OF SOW NUTRITION DURING GESTATION ON THE BODY COMPOSITION AND SURVIVAL OF YOUNG PIGS

by

© DANIEL B. OKAI

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

IN

Animal Nutrition

DEPARTMENT OF ANIMAL SCIENCE

EDMONTON, ALBERTA

SPRING, 1977

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The effects of sow nutrition during gestation on the body composition and survival of young pigs" submitted by Daniel B. Okai, in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Animal Nutrition.

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ABSTRACT

The effects of recommended feed intake (2.0 kg/sow/day, i.e. C-L) or ad libitum intake of a control diet (C-H) or diets containing 10% added sucrose (SU) or 10% stabilised tallow (TA) on sows in late gestation were determined in 2 experiments. Response criteria were sow weight changes in late gestation and in lactation, litter performance, sow colostrum composition, sow and piglet blood constituent changes and piglet tissue and carcass composition.

Ad libitum feed intake in late gestation led to significant increases in feed intake ($P<0.01$), weight gain ($P<0.05$) and a higher but not significant weight loss in lactation. Piglet birth weights were 1.34, 1.43, 1.45 and 1.36 kg for the C-L, C-H, SU and TA treatments respectively. The differences were not significant. At 3 weeks of age, the corresponding weights were 4.96, 4.95, 5.41 and 5.19 kg. The difference between the C-L and C-H groups was not significant but the difference between these values and that for the SU treatment was significant ($P<0.05$). Piglets from the TA treatment weighed significantly ($P<0.05$) less at weaning than the SU piglets but were heavier ($P<0.05$) than the C-L and C-H piglets. Numbers of pigs born were similar for the 4 treatments; the numbers weaned and percent stillborn per litter in the 4 treatments were also similar. The gross composition of the colostra from the 4 treatments was similar but there were significant ($P<0.01$) differences in the levels of palmitic and oleic acids present. Colostrum from the TA sows had more oleic acid than any other group but this was only significantly

($P<0.05$) different from that of the C-H and SU sows. The C-L and TA colostra however, contained significantly ($P<0.05$) lower levels of palmitic acid.

Sow blood serum profiles were similar at the start of the second experiment. The only treatment effect at Day 108 of gestation was an increase in the level of cholesterol with ad libitum feeding. Cholesterol level in the serum of the TA sows was only significantly ($P<0.05$) different from that in the C-L sows. Blood serum profiles of newborn pigs were similar for all 4 treatments. There were significant changes in the levels of serum urea nitrogen, uric acid, cholesterol, total protein, albumin and bilirubin with age.

Proximate carcass composition at birth was similar for the 4 treatments but TA piglets contained slightly more total lipid at birth. Again, significant age effects were observed. The fatty acid composition of the carcasses were similar at each sampling period with the exception of the levels of palmitoleic, palmitic, myristic and palmitic acid at birth, 24 and 48 hr. respectively. At birth the glycogen content in the L. dorsi of the piglets was similar for the 4 treatments but in the liver, there was a significant ($P<0.01$) reduction in the glycogen content in pigs from sows fed the TA diet. In both liver and L. dorsi, the glycogen content decreased significantly ($P<0.01$) from birth to 48 hr of age.

ACKNOWLEDGEMENTS

I wish to thank Dr. L.P. Milligan, Chairman of the Department of Animal Science for placing the facilities of the department at may disposal. I am particularly grateful to Dr. F.X. Aherne, Associate Professor of Animal Nutrition for his patient understanding and helpful criticism during the course of this study and especially in the preparation of this manuscript. The useful modifications he suggested to sometimes inadequate facilities were instrumental to the success of the research program. Dr. R.T. Hardin, Professor of Poultry Genetics, Mrs. Dolores Lam and Mrs. Marion Peebles assisted with statistical analyses of the data and their help is acknowledged.

I also wish to express my gratitude to Mr. L. Todd, Mrs. M Fenton, Mr. C. Visser, Mr. G. Stephens and the staff at the Swine Research Unit for helping with various stages of these experiments.

This study was supported in part by grants from the Alberta Agricultural Research Trust and the Alberta Hog Producers Marketing Board. My thanks are expressed to these bodies without whose financial assistance this study could not have been carried out.

Words cannot express my thanks to my wife, Agnes, for her understanding and unstinting assistance at all times, particularly during the period when it became necessary to stay up until the early hours of the day to collect tissues from newborn pigs.

I wish to express thanks to Miss Wendy Beaton for assistance in typing this manuscript.

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INTRODUCTION

The newborn pig is poorly adapted to cope with severe environmental insult; thus poor environmental conditions at birth can lead to preweaning losses of between 20 and 30% and may impair the subsequent performance of those pigs that do survive. In the past, crushing was considered accountable for many of the neonatal deaths in piglets. More recently, nutritional inadequacy and the inability of the newborn pig to maintain body temperature have been implicated in the high pre-weaning loss.

The newborn pig has a relatively large surface area, sparse pelage, no brown adipose tissue for non-shivering thermogenesis and a limited ability to utilize energy sources other than carbohydrates (Stanton and Meuller 1976). With a critical temperature of 33-35°C, the newborn is stressed whenever temperatures lower than these persist in the farrowing barn and in such cases, has to rely upon body reserves to maintain body temperature.

The piglet at birth has two energy reserves; a considerable store of glycogen in both liver and skeletal muscle and a rather limited lipid reserve (1-2% body weight). It has been clearly established that the glycogen reserves are quickly depleted within the first 12-18 hr of life under normal rearing conditions. Lipids are present both as structural entities (eg. phospholipids) and as depots for energy and insulation. However, the small amount present precludes its use as a major metabolic fuel.

Attempts have been made to influence the glycogen and lipid content of newborn pigs by modifying the feed intake of sows either throughout or in late gestation, (Curtis et al, 1965; Vermedahl et al, 1969; Anderson and Wahlstrom 1970; Buitrago et al, 1974a; Friend 1974 and Seerley et al, 1974). However most of these studies appeared to be aimed at trying to demonstrate the effects of less than adequate energy intake on glycogen and lipid reserves of the piglets. Information is thus lacking on the effects of high feed intakes in late gestation on tissue energy stores of newborn pigs.

As has been observed (Buitrago et al, 1974a), there is also very limited information on the blood and tissue composition of the offspring of dams given different feeding levels during pregnancy. Studies undertaken since then have generally served to provide information on blood and tissue components of the offspring of sows fed restricted levels of feed, (Atinmo et al, 1974b; Buitrago et al, 1974a; and Seerley et al, 1974).

The objectives of the studies reported herein were to evaluate the effects of high feed intake by sows in late gestation on blood, milk and certain tissue components and to evaluate the ability of sows thus treated to rear pigs from birth until weaning.

LITERATURE REVIEW

I. INFLUENCE OF DIETARY INTAKE AND DIETARY MANIPULATIONS ON PIGLET BIRTH WEIGHT AND ON SOW REPRODUCTIVE PERFORMANCE

In this discussion, the effects of gestation and (where necessary) lactation treatments on piglet birth weight, weight gains from birth to weaning, pre-weaning losses and sow weight changes from breeding to parturition will be reviewed.

I.1. Effects of Feed Intake

In sows, pregnancy instead of imposing a burden on energy requirements, improves the efficiency with which the diet is utilized (Lodge, 1972). Recently, studies on the effects of feed intake of sows on birth weight of piglets have been reported by Elsley et al (1969), Buitrago et al (1970), Frobish and Steel (1970) and Frobish et al (1971). These authors reported progressive increase in birth weight as the sow's daily feed allowance increased from 1.6 to 5.5 kg. On the other hand, Lodge et al (1966a) and Baker et al (1969) failed to observe a significant increase in birth weight as feed intakes increased from 1.4 to 3.0 kg per sow per day. Lower feed intakes of 0.9 to 1.4 kg per day led to decreases in birth weight (Lodge et al, 1966a; Baker et al, 1969).

Lodge (1958) studied the effects of 2 lactation treatments. In the high regimen, sows were fed 3.6 kg of meal per day plus 0.4 kg per piglet while the low level of intake allowed 0.9 kg per day plus 0.5 kg per piglet. He observed that the sows on the low intake levels lost more weight during lactation

but gained more during pregnancy. Mean individual weaning weights were not significantly different. Eyles (1959) compared feed intakes of 1.8 and 0.9 kg per sow per day during the first 13 weeks of gestation. He reported similar litter sizes but higher piglet mortality with sows which had been fed 1.8 kg meal. He attributed the higher mortality to over-fat sows. There were no differences in piglet weights at 3 or 8 weeks of age.

The reproductive performance of normally-fed (NRC requirements were met) and restricted sows was determined by Dean and Tribble (1961). Gestation weight gains for the normal and restricted sows were from 45.9 to 49.5 kg and from 23.6 to 40.9 kg respectively. The latter required less assistance at farrowing, had a lower % stillborn but had a similar gestation length. The sows fed the restricted level of feed farrowed pigs of a lower birth weight and weaning weights at either 6, 7 or 8 weeks of age were also lower. They stated that sows and gilts that gained in condition during gestation, lost condition during the lactation period. Condition was defined as change in weight or backfat thickness. Essentially similar results were obtained by Lodge et al (1961) who also stated that, even on a high scale of feeding during lactation, there was a marked body weight loss. Clawson et al (1963) and Curtis et al (1965) reported a significant increase in birth weight with increase in the level of feed intake during gestation.

Lodge et al (1966a,b) studied the effects of 3 levels of feeding during pregnancy on reproductive performance and sow weight changes. Sows received either 2.7 kg, 1.4 kg or 1.4 kg in the first 76 days and 2.7 kg until parturition. They found that the 3 treatments did not influence pre- and post-natal mortality. The birth weights of 1.3 kg, 1.1 kg and 1.2 kg were significantly different ($P<0.001$). Mean piglet weight at 3 and 8 weeks of age were 4.8, 14.2 kg, 4.3, 13.6 kg and 4.6, 13.4 kg respectively. However, only the differences at 3 weeks of age were significant ($P<0.05$). Pregnancy weight gains for the 3 groups were 44.1 kg, 4.1 kg and 19.1 kg. The corresponding weight changes during lactation were -17.3, +3.2, -4.5 kg and were significantly different. The performance of sows fed either at a low (1.8 kg/day) or high (2.7 kg/day) level during the last third of gestation and at a low (2.7 kg/day) or high (3.2 kg/day) level before and 21 days after breeding were compared by Mayrose et al (1966). They found that when the level of feed intake was increased in the last third of gestation, there was a significant ($P<0.01$) increase in sow weight gain, but there was no significant effect on piglet birth weight or weaning weight.

The effects of amount and distribution of feed intake during pregnancy on sow's reproductive performance has been studied by O'Grady (1967). He concluded that sows fed 2.7 kg/day during pregnancy lost weight during lactation while those on low feed (1.4 kg/day) gained or maintained weight. These treatments significantly influenced both litter weight at

birth and at weaning, with the high feed intake leading to superior piglet weights. Adam et al (1971) and Frobish et al (1971) later reported similar findings. From breeding to farrowing, Baker et al (1969) fed gilts 0.9, 1.4, 1.9, 2.4 or 3.0 kg/day of a diet designed to be adequate or super adequate in all nutrients when fed at 1.9 kg. They found that these levels of feed intake did not affect number of pigs farrowed or weaned (3 weeks of age). Birth and weaning weights and gilt weight gain increased as gestation feed intake increased. They noted, however, that high gestation feed intake led to a higher lactation weight loss and that birth weight and weaning weight reached a plateau at 1.9 and 2.4 kg gestation feed intake, respectively, Elsley et al (1969) observed a higher piglet birth weight with higher feeding levels in gestation. They also observed that the higher birth weight also led to a significant difference in piglet weight at weaning (8 weeks). They confirmed that gestation weight gains were negatively related to lactation weight loss or gain.

In addition to a significantly ($P<0.05$) lower birth weight of piglets from sows fed 1.36 kg throughout prebreeding and gestation, Vermedahl et al (1969) reported a lower 3-week weaning weight ($P<0.01$) and a lower sow weight loss ($P<0.01$) during lactation in comparison to the performance of sows receiving 2.27 kg of feed. They showed that neither the vigour nor the number of live pigs at birth was affected by the treatments imposed. The effects of sow treatment on 3-week weaning weight were not noticeable when the offspring reached

slaughter weight.

Lodge (1972) reviewed the literature available on reproductive performance and noted that the majority of research results suggested an inverse relationship between gestation feed intake and voluntary intake during lactation, leading to a higher weight loss.

I.2. Effects of Protein and Energy Intake

The effect of protein restriction on gilt performance has been demonstrated by Pond et al (1968); a "protein-free" diet fed from Day 24 of gestation did not lead to a significant decrease in birth weight but at 6 weeks of age, the piglets had a lower weight ($P<0.01$) than a control group. They attributed this to a reduction in milk production. However, Atinmo et al (1974a, b) have observed a significant reduction in birth weight when dams were fed protein-restricted diets. They also reported an 11.2 kg weight loss after parturition in such gilts; but gilts from the control and energy-restricted group gained weight. They demonstrated that post-natal growth was also affected up to slaughter age.

Smith (1960) reported that a high energy (1212 Mcal in total) intake in gestation and a low lactation (587 Mcal for 8 week lactation) energy intake led to a high gestation gain (51.4 kg) and a high weight loss (-23.6 kg) during lactation. Corresponding values for low gestation-high lactation and low gestation-low lactation treatments were 20.9, 3.5 kg and 21.8, -24.9 kg. He concluded that the practice of building up sow body reserves during gestation and dissipating these

during lactation was energetically inefficient. The influence of source and level of energy and protein intake on sow performance during growth, gestation and lactation has been reported by Bowland (1964). He obtained similar performance for (1) sows fed 2.7 kg per day during gestation and (2) sows with an 8% dietary restriction. The addition of 20% extra protein or 15% stabilised tallow to supply 20% of the energy in the rations of feed-restricted sows, did not have any significant effect on number or weight of pigs born alive or weaned. Sows fed the tallow diet had heavier weights at weaning after 2 lactation. He noted that litter birth weight and weaning weight were significantly correlated ($r=0.60$) and the former was also associated with sow weight gain during gestation ($r=0.54$). Bowland (1964) suggested that, within limits, any feeding method should aim at a low gestation weight gain. O'Bannon et al (1966) observed slaughter weights of 123.6, 95.5, 107.1 kg in breed gilts fed 3.3, 2.8 and 2.7 Mcal DE/kg diets respectively from 48.3, 47.7, 47.1 kg through breeding at 102.3, 81.4 and 91.2 kg. They noted that high daily weight gains by the high energy group were negatively correlated ($r = -0.46$) with the number of viable embryos. Three energy levels in late gestation (i.e. 2.4, 3.4 and 4.4 Mcal ME/day) were compared by Anderson and Wahlstrom (1970). Litter weight gain to 3 days of age, but not gestation length, was significantly ($P<0.05$) affected by the treatments. Gilts fed 3 energy levels (i.e. 3.0, 6.0 and 9.0 Mcal ME/day) in gestation produced piglets

with weaning weights of 11.9, 12.3 and 12.2 kg respectively ($P<0.05$). Weight gains of those pigs carried to market weight were not different (Buitrago et al, 1970). In another gilt study, Buitrago et al (1974b) observed that feeding 2.8, 5.9 and 9.0 Mcal GE/day led to prepartum gilt weights of 137, 173 and 192 kg, respectively ($P<0.01$). The recorded birth weights of pigs from sows given the low energy intake were significantly less than those for the medium and high groups. Gilts that received the high energy levels during pregnancy lost more weight during the 8-week lactation but the mean weaning weights of the piglets were quite similar. In a previous study, Buitrago et al (1974a) compared 2 energy (i.e. 2.2 or 8.0 Mcal DE/day) levels throughout gestation. The corresponding birth weights were 0.76 and 1.10 kg.

In 2 rather similar studies involving 10% corn oil or corn starch diets having similar energy contents, Friend (1974) and Seerley et al (1974) obtained conflicting results. While Friend (1974) demonstrated that the corn starch resulted in a higher birth weight ($P<0.01$) and 35-day weight gain ($P<0.05$), Seerley et al (1974) reported that the corn oil group had slightly higher birth and 21-day weights. There was no treatment effect at weaning. Of significance, however, is the fact that whereas Friend (1974) fed the 2 diets throughout the lactation, Seerley et al (1974) fed a common diet after parturition. Moreover, Friend (1974) noted that sows fed the corn oil diet produced pigs with slightly higher 21-day weights. The inclusion of either lard or corn oil in

gestation diets for gilts did not lead to significant differences in either birth or 3-week weight according to Malm et al (1976).

In summary there is ample evidence that a high feed or energy intake during gestation leads to higher gestation weight gains. It is less clearly established whether such treatments affect the performance up to weaning of the piglets. The higher gestation weight appears to be highly related to weight losses during the lactation period. At present, therefore, a low (2.0 kg) but constant feeding level is recommended during gestation. Some of the adverse effects of high feed or energy intake in gestation have been mentioned by Vermedahl et al (1969) and Buitrago et al (1974b). Very few of the studies to date have focused attention on the last 2 weeks or less of gestation and those that have, (Friend, 1974; and Seerley et al, 1974), were mainly designed to show effects of lower energy intake or the effects of dietary energy source on birth weight and litter performance. Thus the responses of sows in late gestation to ad libitum feeding have not been established. In this thesis, an attempt will be made to determine sow reproductive performance, litter weights and survival when sows are allowed high nutrient intakes in late gestation.

II. ENERGY RESERVES IN NEWBORN PIGS

A. GLYCOGEN

Glycogen is a storage polysaccharide entirely composed of glucose residues. The glucose radicals in glycogen are joined by α,1-4 and α,1-6 linkages giving rise to a branch structure with the 1-6 linkages constituting the branch points. Approximately 93% of the glycosidic linkages are of the 1-4 type and 7% of the 1-6 type. In the liver, glycogen is used as a source of glucose and in muscle and other tissues it also provides glycolytic intermediates. Large amounts of glycogen are stored in both the liver and muscles of fetal pigs during late gestation. The importance of glycogen to the newborn pig cannot be over emphasized. The neonatal pig has very little body fat and approximately 80% of the substrate metabolised soon after birth is glycogen (McCance and Widdowson, 1959b). The metabolised substrate is important for maintenance of body temperature, evaporation of amniotic fluid from the body, rise in blood glucose level and maintenance of normal behavior in the first few hours after birth (Shelley 1961).

This review will concern itself with the level of glycogen in the liver and skeletal muscle of newborn pigs from sows that have been exposed to varying nutritional regimens throughout or during the last 2 weeks of gestation. Unless otherwise specified, the term "newborn" will refer to piglets observed immediately at birth and not a few hours later. Mersmann (1971) has suggested that the extent and

magnitude of the metabolic changes which occur immediately after birth makes this distinction mandatory. In instances where the values for glycogen are not available, the values for total carbohydrate in the tissues will be reported. According to Shelley (1961), good agreement has been reported between values for total carbohydrate and glycogen in skeletal muscle and liver samples.

A 1 Normal Glycogen Level in Newborn Pigs

A 1.a. Liver

As early as 1952, Morrill (1952a) in studies of baby pig mortality reported liver glycogen concentrations of 18.5 to 90 mg/g with a mean of 52 mg/g in 14 piglets ranging in age from 0 to 15 hr. In subsequent studies, he employed histological preparations to show the depletion of glycogen with age (Morrill 1952b), and the influence of low enviornmental temperature (15°C) and fasting on liver glycogen concentration (Morrill 1952c). Shelley (1961) summarized the available literature on glycogen deposition pattern, total reserves and their changes at birth in several mammalian species. Quoting McCance and Widdowson (1959b), Shelley (1961) reported a liver glycogen concentration at term of about 80 mg/g wet weight for pigs. However, Curtis et al (1966) using 21 newborn pigs observed a mean tissue concentration of total carbohydrate of 121.9 mg/g wet weight. They noted a significant reduction in this reserve at 8 hr of age, having recorded a value of 79.6 mg/g wet weight for 19 piglets. Swiatek et al (1968) also determined liver

glycogen level at birth and its changes with fasting. They observed liver glycogen levels at birth of 148 mg/g and noted that these were 3-5 times greater than those observed in more mature swine. Liver glycogen decreased to the levels seen in older animals within 18 hr of delivery. In an experiment designed to study (inter alia) the effects of energy intake by gilts in late gestation on reproductive performance and certain chemical characteristics of the offspring, the highest energy intake of approximately 4.4 Mcal ME per day led to a liver glycogen concentration at birth of 121.5 mg/g wet weight in the offspring (Anderson and Wahlstrom, 1970). This was higher than the levels determined in the offspring of dams fed lower energy levels. In this same experiment, the inclusion of Dichlorvos (2,2-dichlorovinyl dimethyl phosphate) in the dam's diet led to a higher liver glycogen content in the newborn pig at birth (123.6 versus 107.1 mg/g wet weight for the control's offspring). Mersmann and Houk (1971) estimated the liver glycogen levels of piglets ranging in age from 0 to 65 days. They observed a very high level of 230 mg/g wet weight at birth, this decreased to a minimum of about 50 mg/g wet weight at 2 days of age. A stable level of 70 mg/g wet weight was attained from Day 6 onwards. In a subsequent paper, Mersmann (1971) reported a value of 194.2 mg/g wet weight at birth, with the minimal level at Day 2 and again adult levels were observed from Day 6 onwards. Holub (1971), however, did not obtain as high a level of liver glycogen in

his neonatal pigs. The highest level of about 72 mg/g wet weight was obtained in piglets that were almost 24 hr old. It is thus probable that there had been some loss or utilization before sample collection and determination of glycogen. In his studies, he confirmed the reported glycogen depletion with age and its later stabilization at adult levels.

The consistently high level of glycogen at birth observed by Mersmann and Houk (1971) and Mersmann (1971) were confirmed by Mersmann et al (1972). They obtained levels of approximately 210 mg/g wet weight in newborn pigs with the lowest concentration of liver glycogen appearing in piglets killed at 2 days of age. In an effort to determine changes occurring between birth and 2 days of age, piglets were sacrificed at 0, 6, 12, 24 and 48 hr of age. The observed liver glycogen levels were 252, 158, 114, 96, 85 mg/g wet weight respectively. They concluded that liver glycogen decreased rapidly during the first 6 hr postpartum and continued to decrease more slowly thereafter. Padalikova et al (1971) have studied the glycogen deposition pattern during the last third of intrauterine life. At Day 114 of gestation, they reported a fetal liver glycogen content of 109 mg/g wet weight. In further studies (Padalikova et al 1972), they determined the glycogen content in 4 different liver lobes and concluded that the average glycogen concentration was the same in all the 4 lobes from Day 74 to Day 114 of gestation. Stanton and Mueller (1973b) have determined the metabolic responses to cold in piglets

of various ages. The liver glycogen level in 3-hr old control piglets was 144 mg/g wet weight. This value is similar to that reported by Mersmann et al (1972) for 6-hr old piglet liver and tends to support their claim that the first 6 hr post-partum are quite crucial with regard to glycogen depletion in the liver. In the 24-hr old piglet, the liver glycogen concentration was 32 mg/g wet weight. Mersmann (1974) summarized the metabolic patterns in neonatal swine and indicated that in the newborn pig the liver glycogen may be as great as 200 mg/g wet weight and was at a minimal level 12 to 18 hr post-partum. He related the high glycogen level at birth to the high activity of glycogen synthetase in the liver.

Normal energy intake in the last 5 days of gestation has been compared to a low energy intake with respect to its effects on liver glycogen concentration at birth (Seerley et al, 1974). Liver glycogen levels of 217 mg/g and 202 mg/g were recorded when corn starch and corn oil respectively were used in the rations. Seerley and Poole (1974) commented on the lack of sufficient data with regard to carcass composition of baby pigs at birth and the changes that occur in the potential energy sources available to the piglet. They determined the carcass glycogen level in newborn pigs and obtained a level of 37.8 mg/g wet weight. They, however, did not determine the level in the liver per se. Using 3-hr old piglets which had suckled, Stanton and Mueller (1974) observed a liver glycogen concentration of 120 mg/g wet weight and noted a rapid decline in glycogen

levels when the piglets were fasted. It is of interest to note that in a study with 35-day-old fed pigs to determine differences in glycogen level from 12 different sampling sites of the same liver lobe, they reported that the glycogen content of the samples from one lobe varied from 67-155 mg/g wet weight in one liver and from 72-107 mg/g wet weight in another. It is not known if differences exist in the glycogen content of liver sampling sites of newborn pigs even though Padalikova et al (1972) have reported that there were no differences in glycogen levels of 4 liver lobes in pigs at Day 114 of gestation. Randall and L'Ecuyer (1976) have noted that at Day 112 of gestation, the liver glycogen level in the fetuses was 102.8 mg/g wet weight. They pointed out that studies relating to the time of deposition of the glycogen reserves are limited.

Unpublished data from Iowa (Aherne, personal communication) on the time of glycogen deposition showed that, at Day 113 of gestation, the fetal liver contained 140.9 mg/g wet weight of glycogen and this decreased to 23 mg/g wet weight 3 days post-partum. Furthermore, Elliot and Lodge (personal communication) have observed that the liver glycogen level in newborn pigs is 143 mg/g wet weight with sows fed recommended feed levels. Siers et al (1976a) in studies on the effects of late gestation feeding of Dichlorvos, observed a level of 99 mg/g wet weight and 100 mg/g wet weight for the 2.5-hr-old piglets of control and Dichlorvos-fed sows respectively. These results do not agree with those reported by Anderson and Wahlstrom (1970) who have reported that Dichlorvos-

feeding of sows increases liver and muscle glycogen level of newborn pigs, but both values were similar to that reported by Widdowson and Crabb (1976).

A 1.b. Muscle

According to Shelley's (1961) summary of the literature available up to that time, the concentration of glycogen in skeletal muscle in newborn pigs was 70 mg/g wet weight and she indicated that this level was at least twice the corresponding adult level. She further stated that it usually fell to or below the adult level within 1-3 days of birth. In 1966, Curtis and his co-workers (Curtis et al, 1966) determined the total carbohydrate content of 2 muscles, the Gluteus maximus (G. Max.) and the Longissimus dorsi, (L. dorsi) in newborn pigs. They reported levels of 80 mg/g and 71.6 mg/g wet weight respectively and noted that, while the total carbohydrate content of G. Max. had decreased significantly by 8 hr post-partum, the level in the other muscle had not changed. The probable reason was that the rate of glycogen reserve utilization in skeletal muscle was proportional to the activity of the particular muscle and they recommended that the particular muscle sampled should be identified. Anderson and Wahlstrom (1970) collected semitendinosus (ST) muscles from piglets killed at birth and at 6, 12, 18, 24, 36, 48 and 72 hr after birth and reported values ranging from 85 mg/g at birth to about 26 mg/g wet weight at 72 hr of age. The effect of late gestation energy intake on muscle glycogen level at birth was also studied in

this experiment; the "high" energy intake of approximately 4.4 Mcal ME led to muscle glycogen concentrations of 90.2 mg/g wet weight at birth. The addition of Dichlorvos to the sows' diet in late gestation did not have any effect on the glycogen content of the ST muscle at birth. Holub (1971), while failing to specify the particular skeletal muscle studied, reported that the glycogen content was 65 mg/g wet weight on the day of birth; this had decreased to 15 mg/g at Day 30. He did observe that the period from birth to 7-10 days of age was a period of dynamic changes in muscle glycogen levels.

In unspecified skeletal muscles taken on Day 94, 104 and 114 of gestation, Padalikova et al (1971), reported glycogen values of 24, 61 and 84 mg/g wet weight respectively. In anotner experiment involving 138 fetuses from 13 sows, the glycogen content of the Quadriceps femoris (QF) was determined at Days 74, 84, 94, 104 and 114 of gestation, (Padalikova et al, 1972). They found glycogen levels ranging from 14 mg/g for 74-day-old fetuses to 85 mg/g for 114-day-old fetuses and considered the period from Day 94 to Day 104 of gestation to be a time of significant increases in glycogen level in the muscle studied. However, these myscle glycogen levels are not as high as those obtained by Mersmann et al (1972). Using unspecified skeletal muscles of piglets ranging in age from 0 hr to 6, 12, 24 and 48 hr they found glycogen levels of 137.3, 86.3, 73.3, 62.4 and 66.8 mg/g wet weight, respectively. There is thus quite a rapid decrease from birth to 6 hr as was found with liver

samples taken during the same experiment. In a subsequent study in the same laboratory, Stanton and Mueller (1973b), using the Biceps femoris (BF) muscle, studied muscle glycogen content after cold exposure of piglets aged 3 and 24 hr. In the 3-hr-old piglet, the initial glycogen content was 110 mg/g, this was significantly reduced to about 90 mg/g after 2 hr at 5°C. In the 24-hr-old piglet, the level was again significantly reduced from 75 mg/g to 55 mg/g after a similar cold exposure. Perhaps the unidentified muscle used by Mersmann et al (1972) may have been the BF muscle since (1) Stanton and Mueller were involved in that study and (2) the difference between the 137.3 mg/g obtained at 0 hr and the 110 mg/g obtained at 3 hr in the latter study could be expected to be due to glycogen depletion.

The information available up to 1974 on the metabolism of the glycogen store in skeletal muscle has been summarized by Mersmann (1974). He indicated that skeletal muscle levels may reach 120 mg/g wet weight and do not decrease as rapidly after birth as does liver glycogen. Seerley et al (1974) studied the effects of level and source of sow's energy intake in late gestation on tissue glycogen. These authors analyzed for the glycogen content of the ham muscles and the L.dorsi; and reported values of 125 and 147 mg/g respectively when corn starch was the energy source whereas the corresponding values for the progeny of sows fed corn oil supplemented diets were 121 and 150 mg/g. They thus confirmed the observation of Curtis et al (1966) that skeletal muscles can vary in glycogen content.

Stanton and Mueller (1974) have reported glycogen levels in BF muscle of 3-hr -old piglets of 85 mg/g wet weight. Randall and L'Ecuyer (1976) determined the deposition pattern in muscle taken from the lateral aspect of the thigh. They found that at Day 112 of gestation, the thigh muscle contained 69.6 mg/g wet weight of glycogen. Siers et al (1976a) have reported the glycogen content of the Triceps femoris (TF) of 2.5-hr -old pigs to be 81 mg/g wet weight. Late gestation Dichlorvos feeding of the sows did not have an effect on muscle glycogen level of the piglet. Finally, Elliot and Lodge (personal communication) have found skeletal muscle glycogen levels of 102 mg/g wet weight in the progeny of sows adequately fed throughout gestation while Widdowson and Crabb (1976) have reported levels of 56.0 and 61.6 mg/g wet weight for the gastrocnemius and QF muscles respectively.

A 2 Glycogen Reserves of Piglets From Sows Exposed to Various Dietary Manipulations at Different Stages of Gestation

There have been relatively few studies on the effects of dietary manipulations of the pregnant sow on the glycogen reserves of the liver and skeletal muscles of newborn pigs. Curtis et al (1965) determined the effects of late pre-partum glucose loading of sows on piglet glycogen reserves. From Day 99 of gestation through parturition, all sows received 1.36 kg of a 3.3 Mcal DE/kg diet per 100 kg body wt. daily; treated sows additionally received 150 g. per 100 kg body

weight of glucose (incorporated into the feed). The glycogen concentration in the liver, L. dorsi and G. max. of 12 piglets from the control sows were 121.2, 67.5 and 74.7 mg/g wet weight respectively while for the 9 piglets from the treated group of sows the corresponding values were 122.9, 77.6 and 85.5 mg/g wet weight. There was no significant treatment effect. A year later the same group (Reedy et al, 1966) again failed to observe a significant treatment effect even though an additional 25 g. of glucose was given for every 100 kg body weight in the experimental group.

Anderson and Wahlstrom (1970) fed 52 primiparous sows 3 dietary energy levels: 2.4, 3.4 and 4.4 Mcal ME per day from Day 104 of gestation until farrowing. They reported liver glycogen levels of 110.9, 113.0 and 121.5 mg/g wet weight respectively in newborn pigs. The corresponding values for the ST muscle at birth were 83.3, 82.8 and 90.2 mg/g wet weight. Seerley et al (1974) compared liver and muscle glycogen levels of newborn pigs from sows either kept to a "low" energy intake (A) or to a normal energy intake by adding corn starch (B) or corn oil (C) to the basal diet fed to the group A sows. Treatments were initiated at Day 109 of gestation. The liver, ham and L. dorsi glycogen levels were 187, 119 and 128 mg/g for treatment A; 217, 125 and 147 for treatment B; and 202, 121 and 150 mg/g for treatment C. The 2 normal energy groups, B and C, had significantly ($P<.05$) more glycogen per unit weight in the L. dorsi, than the A group. Both B and C groups had more glycogen in the liver than

the A group but the differences were only significant in the case of piglets from sows on the corn starch treatment. The offspring of gilts fed either 2.2 or 8.0 Mcal of digestible energy per day during gestation were studied for liver glycogen changes at birth (Buitrago et al, 1974a). They found a value of 23.6 mg/g for the high energy group and this was significantly different ($P<.05$) from the value of 3.3 mg/g in the low energy group. The unusually low glycogen levels observed could be attributed to the fact that some of the pigs were not slaughtered immediately at birth. Sows which were either fed 0.45 kg (low) or 2.27 kg (high) of an adequately balanced diet in late (Day 100) gestation (Elliot and Lodge, personal communication), had liver glycogen concentrations at birth of 117 and 143 mg/g wet weight for the low and high group respectively. The corresponding levels in skeletal muscles were 90 and 102 mg/g wet weight. None of these differences were significant.

This review (summarized in Table 1) has shown that the glycogen concentration in the liver of newborn pigs is consistently high at birth but decreases rapidly after birth. The liver levels reported are generally higher than the levels found in muscle and there is considerable variation between different muscles. Differences in methodology could explain some of the differences in the values reported for similar samples. Another factor could be the tendency of some researchers to describe piglets sampled at "first observation" as newborn pigs. There are relatively few

TABLE 1

SUMMARY: GLYCOGEN LEVELS (mg/g wet weight) IN NEWBORN AND NEONATAL PIGS

A. LIVER

Conc	Age (hours)	Reference
52	0-14	Morrill, 1952a
80	0	McCance & Widdowson, 1959b
121.9+	0	Curtis et al, 1966
79.6	8	"
148	0	Swiatek et al, 1968
121.5	0	Anderson & Wahlstrom, 1970
230	0	Mersmann & Houk, 1971
50	48	"
194.2	0	Mersmann, 1971
72	2	Holub, 1971
210	0	Mersmann et al, 1972
252	0	"
158	6	"
114	12	"
96	24	"
85	48	"
144	3	Stanton & Mueller, 1973b
32	24	"
217	0	Seerley et al, 1974
120	3	Stanton & Mueller, 1974
99+	2.5	Siers et al, 1976a
100.4+	2.5	Widdowson & Crabb, 1976
143.0	0	Elliot & Lodge (pers. comm.)

B. MUSCLE

Level	Type of Muscle	Age (hours)	Reference
70+		0	McCance & Widdowson, 1959b
80+	G. max.	0	Curtis et al, 1966
71.6+	L. dorsi	0	"
85	Semitendinosus (ST.)	0	Anderson & Wahlstrom, 1970
26	Semitendinosus (ST.)	72	"
65		0	Holub, 1971
137.3		0	Mersmann et al, 1972
86.3		6	"
73.3		12	"
62.4		24	"
66.8		48	"
110.0	B. femoris (BF)	3	Stanton & Mueller, 1973b
75		24	"
125	Ham	0	Seerley et al, 1974
147	L. dorsi	0	"
85	B. femoris (BF)	3	Stanton & Mueller, 1974
81	T. femoris (TF)	2.5	Siers et al, 1976a
56.0+	Gastrocnemius	2.5	Widdowson & Crabb, 1976
61.6+	Quadriceps	2.5	"
102.0		0	Elliot & Lodge (pers. comm.)

+Total carbohydrate was measured.

research reports on the effects of dietary manipulations of the feed intake of sows in late gestation on glycogen reserves and these deal primarily with normal and below normal levels of energy intake. In view of the difficulties in establishing an adequate microenvironment for the newborn pig, other dietary methods of increasing the body reserves of the pig at birth should be studied.

B. LIPID RESERVES AND OTHER BODY COMPONENTS

The most variable component of the body is fat; by comparison, the composition of the fat-free body is relatively constant (Widdowson, 1950; Lohman, 1971). As early as 1945, Gortner (1945) studied the composition of the developing fetus. He observed that the lipid content remained at slightly over 1% until the last month of fetal life, at which time it rose slightly to a value of 1.4% near term. Moisture content, however, declined throughout gestation and near term the moisture level was about 85.0%. Five years later, Widdowson (1950) in a comparative study of the chemical composition of newborn mammals, reported that the newborn pig contained 1.1, 11.3 and 84.1% fat, crude protein and moisture respectively. She also found that a small newborn pig had a lower concentration of protein and fat and a higher proportion of water than a heavier one. Spray and Widdowson (1950) investigated some chemical aspects of the growth and development of pigs. The pigs used ranged in age from newborn to 259 days; at birth the % water and fat in the carcass were 84.0 and 1.0 respectively. The % crude protein on a fat-free

basis was about 11.0. McCance and Widdowson (1959b) reported that at birth the pig carcass contained 81.2% water and 1.0% fat. They observed that while the % water did not change after a 24-hour fast, % fat had decreased to 0.79, indicating that very little of the fat in the body had been used. Pomeroy (1960) observed that near term the pig carcass contained 81.2 and 11.5% water and protein respectively. When he compared the smallest and the largest piglets, he found that the former had more water and less protein than the latter. This confirmed the findings of Widdowson (1950) referred to earlier. Manners and McCrea (1963) slaughtered pigs at birth and at Days 2, 7, 14 and 28 of age and studied the changes in their chemical compositions. At birth, the % water, protein, fat and ash on the basis of empty body weight were 82.6, 12.0, 1.2 and 4.2 respectively, the corresponding values for a 2-day-old piglet were 80.3, 13.6, 2.3 and 3.8. They pointed out that % fat in the carcass at 2 days of age was twice that recorded at birth and added that the figures for % water were only approximate since they were arrived at by subtraction of values for protein and ash from that for fat-free body tissue.

Brooks et al (1964) using skinned and boned newborn pig carcasses obtained values of 78.3, 11.9, 2.3 and 1.0 for % water, protein, ether extract and ash respectively. They also found that these carcasses contained 68 mg/g (6.8%) carbohydrate or glycogen. In a second trial, using carcasses that had only been skinned, the values for water, protein, ether extract and ash were 74.5, 11.7, 1.4

and 5.1 respectively. In this instance, the level of carbohydrate was 73 mg/g (7.3%). In 6-day-old pigs, there was 71.1% water, 9.7% ether extract, 14.2% protein, 3.5% ash and 16 mg/g (1.6%) carbohydrate. Using day-old pigs, Wood and Groves (1965) obtained values that were generally similar to those reported by Brooks et al (1964) with skinned and boned newborn carcasses. Curtis et al (1967) while studying the relationship between body weight and chemical composition of pigs at birth, analysed the carcasses of 72 piglets. The water, ether extract, protein and ash contents were 80.2, 0.6, 10.9 and 4.0% respectively. They explained that the minor differences between their values and those reported earlier could be due to differences in carcass preparation techniques, methods of chemical analyses or genotypes of the pigs used. They concluded, based on correlations, that body weight was not positively associated with development maturity of pigs at birth as measured by the chemical composition of the whole body. It is interesting to note that they observed a range of 0.2 to 1.0% ether extract in the newborn pigs.

Brooks and Davis (1969) have determined the changes in the chemical composition of the perinatal pig. Using skinned carcasses from piglets killed at 3 hr after birth they recorded water, protein, ether extract, ash and glycogen contents of 76.5, 11.9, 1.3, 5.2 and 5.1 (51 mg/g) % respectively. The corresponding values for a 2-day-old piglet were 78.5, 12.5, 2.5, 4.4 and 2.2 (22 mg/g) %. No explanations were given for the increase in

% water in the 2-day old carcasses. Curtis et al (1969), while studying the effects of prolonged gestation on piglet thermostability and body composition, obtained values of 79.8% water, 11.6% protein, 1.4% ether extract and 4.0% ash in the carcasses of the offspring of the control dams. They did not observe any significant change or trend with prolonged gestation. Holub (1971) mentioned that in the first 7 to 10 days of life fat gradually becomes quantitatively the most significant organic component of the piglet's body. He indicated that Jezkova (1966) had reported a value of 1.0% fat in newborn pigs. He confirmed the frequently reported decrease in water content and increase in protein content of carcasses during the first 7 to 10 days of age. Horn et al (1973) compared the lipid level of the carcasses of 6-hr old domestic and wild piglets. The determined figures were 2.1 and 3.5% for the domestic and wild piglets. In 54-hr old piglets, the corresponding values were 4.0 and 4.3%. Friend (1974) determined the carcass composition of day-old piglets; he obtained figures of 78.6, 12.6, 1.4, 3.9 and 3.4 (34 mg/g) % for water, protein, fat, ash and nitrogen-free extract (NFE) respectively. He attributed the relatively low NFE value to be due in part to the delay after birth in killing the piglets. While studying the effects of prolonged fasting on carcass composition of neonatal pigs, Seerley and Poole (1974) noted that the newborn pig contained 80.5% water, 10.7% protein, 3.7% ash, 1.7% total lipid and 3.78 (37.8 mg/g) % glycogen. At 3 days of age the corresponding values were 79.0, 12.5, 3.7, 3.3 and 0.65 (6.5 mg/g). In another experi-

ment, Seerley et al (1974) noted that the offspring of dams fed adequate diets containing either corn starch (CS) or corn oil (CO) demonstrated significant ($P<0.05$) differences in their carcass lipid content at birth. The CS group contained 81.0% water, 2.0% lipid, 12.2% protein and 3.6% ash. The corresponding figures for the CO group were 81.3, 2.4, 12.4 and 3.5. Bertsch et al (1976) using similar treatments observed that carcass water, protein, ash and total lipids were not significantly affected by such dietary treatments. They further stated that while % moisture decreased, % protein and total lipids had increased significantly ($P<0.05$) by 3 days of age. Pownall and Dalton (1976) have reported calculated values of 0.0, 2.4, 4.2 and 3.4% fat in newborn, 12-, 24- and 48-hr-old piglets respectively. Carcass body water decreased from 81.7% at birth to 70.9% at 30 days of age.

B 1 Lipid Reserves and Other Body Components of Piglets From Sows Exposed to Various Dietary Manipulations at Various Stages of Gestation

There is a dearth of information on the effects of dietary manipulations of sows on the carcass characteristics of their offspring at birth. Anderson and Wahlstrom (1970) reported liver water levels of 72.7, 73.3 and 73.0% for piglets from sows fed 2.4, 3.4 and 4.0 Mcal ME respectively per day from Day 104 of gestation until farrowing. The corresponding levels of liver fat were 0.96, 1.12 and 0.92%. They also found that liver moisture increased from birth (73.3%) to 18 hr of age (78.4%) and then decreased steadily

from 18 to 72 hr of age. A similar significant pattern of change occurred in liver fat levels. Buitrago et al (1974a) analysed the L. dorsi of piglets from sows fed either 2.2 (L) or 8.0 Mcal (H) DE during gestation. The % protein, ether extract, ash and moisture for the L-group were 12.7, 6.9, 1.1 and 79.3. The corresponding values for the H-group were 11.7, 7.9, 1.1 and 79.5. Only the % ether extract values were significantly ($P<0.05$) different between treatments, indicating that a low energy intake would lead to a reduction in piglet carcass fat at birth. A similar trend was observed in the proximate composition of gastrocnemius muscles of the 2 groups; here, however, the differences in the ether extract levels were not significant ($P<0.05$). Seerley et al (1974) determined the proximate composition of newborn pigs from sows on 3 different treatments. The carcasses of the piglets from sows on a low energy (LE) regimen from Day 109 of gestation contained 80.9, 2.0, 12.7 and 3.5% moisture, total lipids, crude protein and ash respectively. In the other 2 treatments, normal energy intake was obtained by feeding either corn starch (CS) or corn oil (CO) and the respective % proximate compositions were 81.0 moisture, 2.0 total lipids, 12.2 crude protein and 3.6 ash for the CS group. In the CO group, the % values were 81.3 moisture, 2.4 total lipids, 12.4 crude protein and 3.5 ash. Again only the total lipid levels were significantly ($P<0.05$) different between the CS and CO pigs. In the same study, per cent total lipids in the liver samples were 3.6, 3.1 and 3.7 for the LE, CS

and CO pigs and in muscles, the figures were 2.6, 2.4 and 2.4 respectively. These differences were not significant ($P<0.05$).

While there is sufficient data on the proximate composition of the newborn and neonatal pigs, there appears to be a dearth in the amount of information available on the effects of high feed intakes in late gestation on the composition of the newborn litter. Any increase in the lipid content of newborn pigs would be quite desirable since, apart from its insulation properties, the piglet is capable of utilising fat for metabolic purposes. It has been shown that the lipid content of the pig at birth can be influenced to some extent by level of nutrition (Seerley et al, 1974). The effects of various energy sources and intakes by sows in late gestation on the carcass composition of their piglets will be examined in this thesis.

C. Carcass Fatty Acids in Newborn and Neonatal Pigs and the Effects of Dietary Manipulations.

The review of the literature thus far has shown that pigs are born with a large glycogen content in the liver and skeletal muscle but with very low fat in both the carcass and the liver. In the neonatal period, changes occur leading to a low glycogen content and a high fat content in both carcass and liver. Brooks and Davis (1969) have reported the changes in fatty acid patterns from Day 98 of gestation to Day 6 post-partum. Using 3-hr -old pigs they found the levels of myristic (C14:0), palmitic (C16:0), palmitoleic (C16:1), stearic

(C18:0), oleic (C18:1) and linoleic (C18:2) acids, as a per cent of these major acids, to be 4.1, 30.6, 11.9, 13.2, 33.5 and 6.8 respectively. They noted that the concentration of C18:2 increased from 6.8 to 13.9% between 3 and 48 hr after birth. Palmitic acid increased from 30.6 to 33.3% in the same time period while there was a decrease in the levels of C14:0, C16:1 and C18:0. Only the differences in C16:1, C18:0 and C18:2 were significant ($P<0.05$), however. A similar pattern of change occurred in liver samples with the exception of C18:0 which increased from 15.7 to 21.0% between 3 and 48 hr after birth. Friend (1974) fed 22 sows a basal diet with either 10% corn oil (CO) or 10% corn starch (CS) added for 5 days before farrowing. On analysing the carcasses of day-old pigs from these treatments, he found that the inclusion of corn oil had resulted in a significantly ($P<0.01$) higher proportion of C18:2 in the CO fed pigs. The detailed (%) analysis for the CS and CO groups respectively were C14:0=4.3, 3.9; C16:0=29.7, 27.8; C16:1=11.1, 9.2; C18:0=8.2, 7.6; C18:1=32.4, 31.2 and C18:2=14.3, 20.2. The differences in the proportions of C16:0, ($P<0.05$), C16:1 and C18:2 ($P<0.01$) were significant. In studies on the effects of prolonged fasting on carcass composition, Seerley and Poole (1974) have observed that in the newborn carcass, the levels of C14:0, C16:0, C16:1, C18:0, C18:1, C18:2, C18:3 and C20:4 were 3.1, 25.0, 9.6, 13.6, 30.0, 5.6, 0.5 and 5.6% respectively. The corresponding values for a 3-day-old fed pig were 2.0, 23.7, 6.6, 9.1, 34.7, 17.0, 0.6 and 2.8 %. The increase or decrease

in the proportions of C14:0, C16:1, C18:0 C18:2 and C20:4 from birth to 3 days of age were significant ($P<0.05$). The per cent fatty acid composition of skeletal muscle and liver samples of newborn pigs from sows fed either low energy (LE) or normal energy intake using corn starch (CS) or corn oil (CO) in late gestation has been determined by Seerley et al (1974). In the LE group, the per cent of C14:0, C16:0, C16:1, C18:0, C18:1, C18:2, C18:3 and C20:4 in muscle were 3.5, 29.7, 10.4, 11.2, 30.9, 5.7, 0.2, and 4.3 respectively. The corresponding figures for the CS and CO groups were 3.4, 3.1; 29.9, 29.6; 10.1, 9.0; 11.4, 11.9; 30.8, 30.1; 5.3, 8.2; 0.1, 0.1 and 4.6, 4.3. Based on the figures for both liver and muscle samples at birth, they concluded that the CO piglets had significantly ($P<0.05$) more C18:2 than the LE and CS groups and attributed this to the fact that corn oil has high levels of C18:2. In another experiment using similar treatments and feeding period, Bertsch et al (1976) have reported no significant difference in the proportion of C14:0, C16:0, C18:0 C18:3 and C20:0 in the pig's carcass at birth.

The purpose of this literature review was to describe the fatty acid pattern of the pig at birth, the changes they undergo during the neonatal period and to determine if the pattern can be changed by dietary means. That such a change is possible has been shown by the studies of Friend (1974) and Seerley et al (1974). Both groups used corn oil which is high in C18:2 and reported higher C18:2 levels in the carcasses of the progeny. However there is evidence (Miller et al,

1971a, Seerley & Poole, 1974) that the rate of utilization of C18:2 is not as high as for other fatty acids. It was thus considered desirable to determine if other fatty acids would respond to higher levels of feeding than those imposed by either Friend (1974) or Seerley et al (1974).

C 1 Fatty Acid Composition of the Blood Serum of Newborn Pigs

From the previous review of the literature it was evident that the newborn pig has only a small amount of total body lipid and this could preclude lipid stores as a major metabolic fuel. Circulating free fatty acid levels in the newborn pig are low (100 uEq./100 ml) and increase slightly during starvation (Mersmann 1974). The free fatty acid levels increase greatly within a few hours after birth, most probably because of the dietary intake of lipid from milk. Very few studies have been undertaken to determine the fatty acid composition of serum from newborn pigs and the changes that occur during the neonatal period. Hill (1965) determined the serum fatty acid composition of growing miniature swine; while he did not report any data for newborn pigs, he suggested that his unpublished data on such animals were in close agreement with the serum fatty acid levels found in growing pigs. Leat (1966) reported that newborn pig's plasma contained 2.1% of C14:0, 23.1% of C16:0, 10.5% of C16:1, 11.8% of C18:0, 36.9% of C18:1, 5.5% of C18:2, a trace of C18:3, 1.1% of C20:3 and 6.3% of C20:4. Seerley and Poole (1974) studied the effects of prolonged fasting on the blood fatty acids of neonatal swine and plotted the changes in blood fatty acid pattern from birth

to 3 days of age. Their values for serum content of C14:0 C16:0, C16:1, C18:0, C18:2, C18:3 and C20:4 were 4.8, 22.8, 8.5, 10.0, 27.0, 5.5, 0.2 and 5.5; these being reported as a % of methyl esters. They noticed that by 6 hr of age the fatty acid pattern had started to change with decreases occurring in the levels of C14:0, C16:1, C18:0 and C20:4. Except for C18:0 this trend continued throughout the neonatal period up to 3 days of age. It is worth noting that the values reported by Leat (1966) for newborn pigs are quite comparable of those of Seerley and Poole (1974). Seerley et al (1976) have observed that a 4-hr cold (8°C) stress in 24-hr-old pigs led to a decrease in serum C18:1 and C18:2; they suggested that these had been used for energy metabolism. In another report, Bertsch et al (1976) have indicated that serum of pigs from sows fed corn oil in late gestation had more C18:2 ($P<0.01$) but significantly less C16:0, C16:1 and C18:1 than a group whose dams had a corn starch diet. However, whether this result was from newborn pigs or from neonates was not made explicit in this report.

In conclusion, it would seem from the literature reviewed that there are very limited data on the free fatty acid composition of the serum or plasma of newborn pigs. It cannot be assumed that it is similar to that in young or old pigs since Seerley and Poole (1974) have observed changes. Moreover, Yiu et al (1976) have noticed that age had a significant effect on the free fatty acid level and pattern in plasma.

III. SOME SERUM BIOCHEMICAL PARAMETERS IN NEWBORN PIGLETS AND SOWS - NORMAL VALUES AND CHANGES CAUSED BY DIET

III.1 Newborn and Neonatal Pigs

III.1.1 Glucose, Cholesterol, Total Protein and Urea Nitrogen

In this and subsequent reviews of blood parameters, values will be reported in mg/100 ml of blood serum or plasma except for total protein which will be in g/100 ml.

Glucose levels in newborn pig blood and levels occurring in hypoglycemic situations have been described by Morrill (1952a). He reported a level of 102.6 mg/100 ml in newborn pig blood, with a blood urea nitrogen level of 22.3 mg/100 ml. After a period of suckling he observed values of 114.2 for glucose and 30.8 for urea nitrogen. It is worth noting that his so-called newborn pigs were 1-15 hr old while the suckled pigs were 15 to 150 hr old. Goodwin (1957) obtained a value of 62 mg/100 ml for plasma glucose in newborn pigs and noticed that it rose to a peak of 112 mg/100 ml by 5 hr of age. The amount of serum urea in newborn pigs was also determined by McCance and Widdowson (1959b) who reported a figure of 22.7 mg/100 ml. In another study the same year, these authors (McCance and Widdowson 1959a) reported a serum total protein level of 2.2 g/100 ml in newborn pigs. This increased to nearly 5 g/100 ml in 24-hr old fed pigs. Comparable values have been reported by Miller et al (1961) and Ramirez et al (1963).

Reedy et al (1966) have commented that the feeding of glucose to gilts during late gestation did not lead to any

significant differences in neonatal blood glucose levels for the treated and control group. In another study, Curtis et al (1966) reported glucose concentrations of 89 mg at birth and this rose to 142.2 mg/100 ml whole blood by 8 hr of age. Swiatek et al (1968) have studied starvation induced hypoglycemia in newborn pigs. They noticed that, from a level of 55 mg at birth, blood glucose rose to 75 mg at 6 hr of age. Aherne et al (1969a) found a glucose level of 110 mg/100 ml in the blood of 3-day-old piglets and in a later study (Aherne et al, 1969b) reported that, at birth, the blood contained 82 mg glucose/100 ml of plasma. There was a significant linear increase to 102 mg at 12 hr of age and at 48 hr of age it had decreased 89 mg/100 ml. Bengtsson et al (1969) have also determined blood glucose patterns in the neonatal pig. At birth, they reported a plasma glucose level of 49.9 mg/100 ml; this increased to 91.5 and 99.6 mg between 2-6 and 8-12 hr of age respectively. Subsequently it decreased to 87.3 by 48 hr of age. Anderson and Wahlstrom (1970) have measured the total reducing-sugar level from birth to 72 hr of age and obtained values ranging from 120 mg/100 ml at birth to 117 mg at 24 hr and 122 mg at 48 hr of age. In the same study, gilts fed 2.4, 3.4, 4.4 Mcal ME per day from Day 104 until farrowing had piglets with blood sugar levels of 122.0, 122.0 and 116.0 mg/100 ml respectively.

A low plasma glucose level of 40 mg/100 ml has been reported by Gentz et al (1970), who also noticed a significant ($P<0.001$) increase between birth and 6 hr of age. In an Iowa

study, (Pettigrew et al, 1971) plasma glucose more than doubled (59.8 to 145.7 mg/100 ml) from birth to 2 hr of age, declined sharply from 2 to 8 hr (145.7 to 113.5) and then decreased more slowly to 85.5 mg/100 ml at 32 hr of age. The possible effects of late gestation feeding of corn oil to sows on the blood glucose level of the newborn progeny has been described by Seerley et al (1972). They observed that such piglets contained significantly ($P<0.05$) higher blood glucose than a control group and another treatment group receiving half the normal energy intake.

Mersmann et al (1972) measured blood serum glucose (mg/100 ml) and total protein (g/100 ml) at birth and at 6, 12, 24 and 48 hr of age. They found glucose levels of 37, 115.5, 103.5, 97 and 127 respectively and the corresponding figures for total protein were 2.5, 4.0, 5.3, 4.2 and 4.8 g/100 ml. In a very detailed study of serum biochemical and hematological parameters from birth to 8 weeks of age, Tumbleson and Kalish (1972) reported glucose, cholesterol and urea nitrogen values of 113.9, 84.9, 16.3 mg/100 ml. Total protein was 2.98 g/100 ml. By 8 hr (after ingestion of colostrum) of age, there was an increase in the concentrations of glucose, total protein, blood urea nitrogen, while cholesterol did not change appreciably until 24 hr of age. In another study, using miniature swine, the effects of low protein (0.4%) and normal protein (16.0%) intake by pregnant sows on the blood constituents of their progeny were determined. Serum glucose, cholesterol, urea nitrogen and total protein of 8-hr-old

piglets were 100.0, 104.0, 19.0 (mg/100 ml) and 4.97 g/100 ml for the low protein group and were 141, 124, 44.8 and 6.6 for the normal protein group. However, only the differences in urea nitrogen were significant (Tumbleson and Hutcheson 1972). In a series of experiments, Stanton et al (1973) and Stanton and Mueller (1973a,b; 1974) reported plasma glucose levels of 44 mg/100 ml and 70-95 mg/100 ml in newborn and 3-hr-old pigs. Some blood constituents at birth of offspring of malnourished gilts have been studied by Atinmo et al (1974b). The total plasma protein level of pigs from the control sows were 5.2 g/100 ml whereas the values for pigs from sows restricted in either energy or protein were 4.0 and 4.7 g/100 ml respectively. Buitrago et al (1974a) studied energy level per se and observed that the progeny of gilts fed 2.2 Mcal DE per day throughout gestation had blood glucose, cholesterol and serum protein levels of 100.9, 96.9 mg/100 ml and 4.6 g/100 ml respectively at birth, while sows fed 8.0 Mcal DE/day had corresponding values of 109.6, 85.5 mg/100 ml and 5.6 g/100 ml. Only the serum protein levels were significantly ($P<0.01$) different. Serum glucose levels of between 78 and 85 mg/100 ml have been reported by Friend (1974) in day-old pigs, the lower and higher values being attributable to the feeding of 10% corn oil and corn starch respectively. Seerley and Poole (1974) have observed serum glucose values of 63 mg/100 ml at birth, 103.5 at 6 hr, 100.5 at 24 hr and 94.0 at 48 hr of age. However, in a study of energy restriction Seerley et al (1974) reported a level of 45.7 mg/100 ml for the progeny of the

the restricted group while those of the control sows contained 43.4 and 55.2 mg/100 ml, the latter value being for pigs from sows fed corn oil in their rations. It is of interest that Friend (1974) using comparable treatments obtained the opposite results. Kernkamp (1976) has summarised most of the data available on blood components and has reported values of 92.0 mg/100 ml for glucose and 3.5 g/100 ml for total protein in neonatal pigs. Malm et al (1976) have reported serum cholesterol levels ranging from 53 to 77 mg/100 ml at birth. Siers et al (1976a,b) obtained values of 31.3 and 33.9 mg/100 ml glucose in newborn pigs, while Tumbleson and Hutcheson (1976) determined serum cholesterol levels ranging from 62 at birth to 119 mg/100 ml at 1 day of age and total protein levels of 2.92 at birth rising to 7.53 g/100 ml at 1 day of age.

III.1.2 Lactic Acid (LA), Calcium (Ca), Phosphorus (P), Bilirubin (B) and Uric Acid (UA)

According to Morrill (1952a) the Ca and P levels in serum and the UA level in the blood of pigs less than 15-hr old were 10.6, 7.4 and 1.4 mg/100 ml respectively. In 1- to 6-day-old pigs, the corresponding levels were 12.0, 7.4 and 0.8 mg/100 ml (Morrill, 1952a). Gardiner et al (1953) observed Ca levels of 10.5 mg/100 ml in day-old pigs. Blood levels of LA in newborn pigs increased from 32 at birth to 52 mg ($P<0.01$) at 7.5 hr post-partum according to Curtis et al (1966). They attributed this change to an increasing rate of glycolytic metabolism during this period. In an earlier experiment,

Reedy et al (1966) had observed that oral glucose administration to sows late in gestation had no significant effect on the LA level of newborn pigs. Randall and Penny (1968) confirmed the values of Curtis et al (1966) when they reported that the mean plasma LA concentrations of 74 newborn pigs was 34.0 mg/100 ml while stillborn pigs had blood levels of 159.3 mg/100 ml. They concluded that anoxia during parturition was of major importance in stillbirths. A LA value of 79.1 mg/100 ml was recorded by Pettigrew et al (1971) in newborn pigs. They also mentioned that while no attempt was made to record birth order there was a trend towards greater plasma lactate levels in pigs born later in the litter. The changes in the concentrations of Ca, P and B from birth to 8 weeks of age have been described by Tumbleson and Kalish (1972). At birth, they obtained levels of 11.8 mg Ca, 5.5 mg P and 0.25 mg B/100 ml serum. Ca increased significantly ($P<0.01$) from 24 hr to 3 days of age while B increased significantly ($P<0.01$) from birth to 24 hr of age (0.2 to 1.0 mg/100 ml). In a comparison of the progeny of protein malnourished (M) and protein adequate (C) miniature sows, Tumbleson and Hutcheson (1972) recorded serum Ca and P levels of 10.6 and 6.4 mg/100 ml for the M-progeny and 10.7 and 7.5 mg/100 ml for the C-group. These differences were not significant. Kernkamp's (1976) summary data shows a range of 10-14 and 9-24 mg/100 ml for Ca and P respectively in neonatal pigs, with corresponding means of 11.8 and 16.9; the latter is the highest mean value on record for neonatal pigs. Acc-

ording to Stanton et al (1973), piglets with the highest LA levels showed a more rapid decline in rectal temperature than those with low levels. They suggested that LA levels of 46 mg/100 ml can be expected in newborn pigs. In a subsequent study, Stanton and Mueller (1973a) reported LA values of 20 mg/100 ml in 3-hr- old pigs. In 2 experiments, Siers et al (1976a,b) reported LA levels of 36.1 and 43.5 mg/100 ml in newborn pigs. They also showed a decline in LA level from birth to 3-hr of age which is contrary to what has been reported in the data of Curtis et al (1966).

Of the blood parameters discussed, 2 appear to demand comment. Total protein is low at birth but increases within a few hours. This increase has been attributed to the intake of colostrum or, more specifically, the gamma-globulin portion of the colostrum. Glucose levels in newborn pigs appear to be quite variable; the literature reviewed indicates a range of 31 to 120 mg/100 ml. It is not certain why the differences are so wide but they could be due to (1) the methods of analysis employed; (2) the type of sample {i.e. blood or plasma or serum (McDonald et al, 1964)}; (3) the time the sample was taken (i.e. age of pig sampled); (4) state of nutrition and environment of the sow and piglet and (5) sample collection and preparation; e.g. hemolysis during blood collection has been known to influence some blood parameters. Time interval between blood collection and separation of serum may under some circumstances influence the observed glucose level on analysis.

III.2 Pregnant Gilts and Sows

III.2.1 Glucose, Cholesterol, Total Protein and Urea Nitrogen

There seems to be a dearth of information on blood biochemical parameters in pregnant sows. In this section, the data available will be presented and, whenever necessary, values determined for mature pigs and miniature pigs will be added. Miller et al (1961) have studied swine hematology from birth to maturity. They reported total serum protein levels ranging from 7.5 to 8.0 g/100 ml in pregnant gilts and sows. In 5-month-old pigs, they recorded a value of 6.9 g/100 ml indicating that there is probably an age effect. Tegeris et al (1965) have indicated that blood glucose and urea nitrogen levels in young miniature swine were 103.0 and 13 mg/100 ml respectively. These are comparable to the values of 94.0 and 14.6 reported by Tumbleson et al (1970) for pregnant miniature swine. In that same study, a cholesterol level of 116.7 mg/100 ml and a total protein level of 8.7 g/100 ml serum were reported. Ruiz et al (1971) have compared the serum metabolites of pregnant and hysterectomized gilts fed two levels of energy. They found glucose, cholesterol and urea nitrogen levels of about 65, 90 and 10 mg/100 ml respectively throughout pregnancy. However, while glucose increased to 100 mg/100 ml in the last two weeks of gestation, both cholesterol and urea nitrogen tended to decrease. Tumbleson et al (1970) observed a similar pattern for cholesterol and urea nitrogen.

Nachreiner and Ginther (1972a,b) have determined some serum parameters at Day 30, 60 and 90 of gestation and have reported glucose, cholesterol, urea nitrogen and total protein levels of 89, 76.5 and 13.3 mg/100 ml and 8.2 g/100 ml respectively at Day 90 of gestation. In the periparturient period, the corresponding values were 84.8, 78.6 and 16.1 mg/100 ml and 7.7 g/100 ml between Day 110 and Day 112 of gestation (Nachreiner and Ginther, 1972c,d).

Diurnal changes were studied by Tumbleson et al (1972a) using 11-month-old miniature swine. They observed levels of 56.6-70 mg/100 ml for glucose, 63.0-70.5 mg/100 ml for cholesterol, 8.6-8.8 g/100 ml for total protein and 12.0-13.3 mg/100 ml for urea nitrogen. They concluded that the time of day during which blood samples were collected from miniature swine had only a small influence on interpretation of experimental data. In two subsequent reports, Tumbleson et al (1972b,c) reported serum protein and urea nitrogen levels of 8.5 g/100 ml and 20.8 mg/100 ml for 10-month-old miniature swine. Atinmo et al (1974a) mentioned the lack of information on the blood constituents of pregnant gilts and commented on how they may be affected by nutritional manipulations or physiological status. They found glucose levels in a control group of gilts ranging from 142 to 210 mg/100 ml from early to late gestation. Urea nitrogen and protein values for the same period ranged from 27 to 40 mg and 7.1 to 7.5 g/100 ml respectively. Values for energy and protein restricted gilts were generally lower. Blood samples obtained from sows immediately after farrowing

contained between 46.3 and 47.7 mg/100 ml glucose (Seerley et al, 1974). Kernkamp's (1976) summarized data shows glucose and total protein levels of 95.0 mg and 7.8 g/100 ml for pigs more than 6 months of age; and Malm et al (1976) have observed serum cholesterol levels of 61 to 93 mg/100 ml in pregnant gilts. Tumbleson and Hutcheson (1976) have found that, in minature swine, serum cholesterol levels can decrease from 182 to 50 mg/100 ml; with younger animals and females having the higher values at any specified age from 1 to 36 months.

III.2.2 Ca, P, B and Uric Acid (UA)

Ullrey et al (1967) observed a level of 10.6 mg Ca/100 ml and 7.1 mg P/100 ml serum in 5-month-old swine. Comparable results were reported by Tumbleson et al (1970), viz. 11.2 mg Ca/100 ml and 7.0 mg P/100 ml in pregnant miniature swine. Gestation levels of Ca, P and B in the serum of normal sows have been determined by Nachreiner and Ginther (1972a,b,c and d). Calcium, P, and B levels at Day 90 of gestation were 9.3, 5.9 and 0.34 mg/100 ml respectively (Nachreiner and Ginther 1972a,b). In the periparturient period, the corresponding values were 9.3, 5.8 and 0.45 mg/100 ml. In another miniature swine study, diurnal variations of 10.5 to 10.6 mg/100 ml for Ca, 6.7 to 6.9 mg/100 ml for P and 0.40 to 0.50 mg/100 ml for B were observed (Tumbleson et al, 1972a). However, in a subsequent paper, they reported slightly higher values of 11.8 mg Ca/100 ml and 8.0 mg P/100 ml with 41-month-old miniature swine (Tumbleson et al 1972c). Kernkamp (1976)

has recorded Ca and P levels of 10.9 and 7.0 mg/100 ml respectively in pigs more than 6 months old, while Tumbleson and Hutcheson (1976) have observed Ca levels of between 12.3 and 10.0 mg/100 ml for miniature swine ranging in age from 1 to 36 months respectively. Corresponding values for P were 10.0 and 5.3 mg/100 ml.

Generally, the literature reviewed has shown that most of the parameters studied did not change very much in gestation with the possible exception of the late gestation period. In fact, these values are in some instances similar to those reported for growing pigs by Bowland (1975) and Sarwar and Bowland (1976).

IV GROSS COMPOSITION OF SOW'S COLOSTRUM AND THE INFLUENCE OF DIETARY MANIPULATIONS ON THE FAT CONTENT AND FATTY ACID PATTERN OF COLOSTRUM

Hughes and Hart (1935) reviewed the previous literature and reported the calculated means for several constitutents of colostrum to be 26.4% total solids, 6.4% fat, 16.2% protein, 2.5% lactose and 0.8% ash. They defined colostrum as the milk produced by the sow during the first 60 hr post-partum but, on analyzing their samples, they obtained total solids, fat, protein, and ash values of 31.9, 5.1, 16.6 and 0.6% respectively for colostrum obtained during parturition. Their combined means at partum and post-partum colostrum were similar, for some components, to those obtained by Braude et al (1947). Bowland et al (1949a) updated the literature available and reported that pigs kept in a dry lot had more fat (14.0%) in the colostrum than those on pasture (10.0%) on the third day of lactation. However, there was very little difference in the fat content of the 2 groups during the first day of lactation. In a subsequent paper, (Bowland et al, 1949b), the composition of the colostrum obtained during parturition was given as 22.8% solids, 15.9% solids-not-fat, 11.3% protein, 2.9% lactose and 0.7% ash for sows on pasture. The corresponding values for dry-lot sows were 22.8, 17.2, 14.3, 3.4 and 0.7%. They explained that a higher fat level (Bowland et al, 1949a) in the colostrum of sows on drylot was probably due to fat mobilization from the fatter sows in the drylot. In another report, Bowland et al (1951) observed that the condition of

the sow at the time of parturition influenced the concentration of fat in the colostrum. Mean fat level in the colostrum was 3.9% but sows that were not thin had a colostral fat content as high as 6.2%. Perrin (1955) undertook one of the first studies to determine changes in colostrum at frequent intervals. At parturition he reported a gross composition of 29.4% total solids, 7.0% fat, 22.4% solids-not-fat, 17.2% protein, 2.5% lactose and 0.7% ash. He noticed that 3 hr later, the corresponding values were 29.1, 7.7, 21.4, 16.8, 2.5 and 0.6%. Further declines occurred in the levels of total solids, solids-not-fat and protein while % fat, lactose and ash increased by 24 hr. post-partum. DeMan and Bowland (1963) published a detailed composition of both colostrum and milk including analysis of the fatty acid pattern using gas-liquid chromatography. The gross composition of colostrum in this study was 18.1% total solids, 5.7% fat, 12.4% solids-not-fat and 7.7% protein. The fatty acid composition (%) of colostrum was C14:0=1.4, C16:0=22.5, C16:1=5.0, C18:0=5.7, C18:1=41.7, C18:2=20.9 and C18:3=2.4 They observed that back-fat resembled colostrum fat in fatty acid pattern more than did milk fat. The comprehensive review of von Neuhaus (1961) was summarized by Bowland (1965). Bowland (1965) indicated that there were considerable variations in reported values for all the colostral components analyzed. This was confirmed by the studies of Stinson et al (1967) who obtained colostral fatty acid composition data dissimilar with respect to the C18:1 and C18:2 content reported by deMan and Bowland (1963). Schuld and Bowland (1968) determined the composition of

colostrum from sows receiving dietary rapeseed meal or soybean meal. They found that % total solids was higher ($P<0.05$) in the colostrum of sows that had received rapeseed meal during either the growth or gestation period while % fat was higher in the colostrum of sows fed rapeseed meal during the growth period. They noted that gross composition was within the ranges observed by von Neuhaus (1961) (as cited by Bowland 1965) except for protein content. Fatty acid composition was similar to that reported by deMan and Bowland (1963) and Duncan and Garton (1966) and was not influenced by the dietary treatments. Elliot et al (1971) have analyzed the gross and fatty acid composition of colostrum from sows receiving varying protein levels during the last 30 days of gestation. In colostrum collected 12 hr post-partum, they showed that the level of dietary protein did not significantly affect the total fat, fatty acid or ash content, even though the colostral protein content was slightly greater for the highest protein level (15% crude protein in the diet). The gross composition of this colostrum was 15.5% crude protein, 8.1% fat, 0.7% ash, 30.9% solids and 22.9% solids-not-fat. The fatty acid composition observed in this study was generally comparable to those reported by deMan and Bowland (1963) and Schuld and Bowland (1968). Fahmy (1972) has reported values of 26.7, 17.3, 5.5 and 0.67% for total solids, protein, fat and ash respectively. He determined energy content to be 1.6 kcal/g and stated that the changes in the amount of latent energy followed the changes in the dry matter percentage.

The inclusion of corn oil in the diet in late gestation led to a significant increase in the % C18:2 in the colostral fat (Miller et al, 1971b, Friend 1974, Seerley et al, 1974). Miller et al (1971b) observed only a slight increase in fat content with no major changes in gross composition while Friend (1974) and Seerley et al (1974) reported a significant increase in the fat content of colostrum when corn oil was fed. The fatty acid composition reported in these three studies were generally comparable to those reported previously. Siers et al (1976a) have reported a colostrum energy content of 1.7 kcal/g and protein, dry matter, lactose and ash content of 16.9, 27.7, 2.6 and 1.4% respectively. They also found that % lipid in their colostral sample was 7.3 and that feeding of Dichlorvos in late gestation led to a significant reduction to 5.7%.

The gross composition of sow's colostrum as reported in this review is different from milk in % total solids and protein - both of which are higher in colostrum - and in fat. There are also differences in the levels of certain minerals and vitamins (Bowland 1965). Other differences, according to Pond and Maner (1974), are higher levels of phospholipids, unsaturated fatty acids, vitamins A, C, E and thiamine; and lower levels of non-protein nitrogen, pantothenic acid and niacin. That the diet fed during gestation can influence some constituents of colostrum has been established in the literature surveyed. The review of Bowland (1965) supports the suggestion that the composition of milk can also be changed

by dietary manipulations. The effects of high feed intakes in late gestation on sows' colostrum have not been examined in depth and thus there is the need for more data.

OBJECTIVES

The experiments described below were designed to determine the effects of recommended feed intake (2.0 kg/day) or ad libitum intake of a control diet or diets containing 10% added sucrose or 10% stabilised tallow from Day 100 of gestation until farrowing. The criteria of response were:

(1) Sow weight changes during late gestation and lactation;

(2) litter performance and composition of colostrum;

(3) piglet blood constituent changes;

(4) tissue or carcass composition and their changes during the neonatal period;

(5) the relationship of the above parameters to piglet survival and growth.

EXPERIMENT 1. REPRODUCTIVE PERFORMANCE - SOW WEIGHT CHANGES, LITTER PERFORMANCE AND COMPOSITION OF COLOSTRUM

Experimental Procedures

1. Animals and Diets: There were 2 replicates in this experiment. Replicate 1 was conducted at a commercial farm[1] and involved 25 crossbred and 15 purebred Hampshire litters. Replicate 2 was undertaken at the University of Alberta farm with 42 crossbred sows bred by boars of mixed breeding. All sows were randomly allotted to the same 4 dietary treatments from Day 100 of gestation until parturition. There were unequal numbers of sows in the 4 treatments. Day 100 was chosen in an attempt to reduce the adverse effects of high and prolonged feed intake on sow reproductive performance.

Sows on the first dietary treatment i.e. Control-Low (C-L) received 2.0 kg of a barley-soybean meal diet each day until farrowing. This same diet was fed ad libitum (C-H) to the second group while the third and fourth groups received ad libitum a similar diet that contained 10% sucrose (SU) and 10% stabilised tallow (TA) respectively. The 10% sucrose and 10% tallow replaced barley on a weight basis in the rations. Sucrose was used to promote feed intake over and above that expected from the C-H group and to study how this would influence performance. The stabilised tallow was added in order to study the effects of caloric intake of dams on piglets' performance. Increases have been reported in piglet survival, and piglet and colostral linoleic acid contents when sows were fed corn oil and the inclusion of tallow was also meant to

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[1]Kaveander Farms, Fort Saskatchewan, Alberta. (Owner Mr. C. Visser).

TABLE 2

DIET FORMULATION AND NUTRIENT COMPOSITION

Ingredient (%)	Control	10% Sucrose	10% Stabilised Tallow
Barley	77.0	67.0	67.0
Oats	9.0	6.0	2.0
Sucrose	-	10.0	-
Stabilised Tallow	-	-	10.0
Soybean Meal	11.0	14.0	18.0
Iodised Salt	0.5	0.5	0.5
Calcium Phosphate	0.5	0.5	0.5
Calcium Carbonate	1.0	1.0	1.0
Vitamin-Mineral Premix[1]	1.0	1.0	1.0
COMPOSITION (ANALYSED)			
Ash, %	4.7	4.3	4.6
Crude Protein, %	14.2	13.3	15.5
Gross Energy, kcal/kg	3811.4	3676.2	4302.8
Lipid, %	2.5	2.4	12.5
COMPOSITION (CALCULATED)			
Crude Protein, %	14.4	14.3	15.7
Digestible Energy, kcal/kg	3051.8	2904.9	3649.8
Calcium, %	0.6	0.6	0.6
Phosphorus, %	0.5	0.5	0.5
Lysine, %	0.7	0.7	0.8
Methionine & Cystine, %	0.5	0.5	0.5
FATTY ACID COMPOSITION (% OF TOTAL FATTY ACIDS)			
Myristic, C14:0	0.3	0.3	2.1
Pentadecyclic, C15:0	0.1	0.1	0.9
Palmitic, C16:0	21.6	21.9	23.7
Palmitoleic, C16:1	0.4	0.3	3.3
Stearic, C18:0	2.1	2.2	15.9
Oleic, C18:1	20.4	19.1	35.7
Linoleic, C18:2	48.0	48.9	13.6
Linolenic, C18:3	5.5	5.6	2.3
Others[2] -	1.6	1.6	2.5

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[1]Supplied the following per kg of diet: 120 mg zinc, 10 mg copper, 48 mg manganese, 100 mg iron, 0.1 mg selenium, 12 mg riboflavin, 40 mg niacin, 27 mg pantothenic acid, 28 mcg vitamin B_{12}, 45 IU vitamin E, 7500 IU vitamin A and 700 IU vitamin D_3.
[2]Others include margaric (17:0) and arachidic acid (20:0).

give indications of changes, if any, in these parameters. Attempts were made to obtain isonitrogenous but not isocaloric diets as indicated by the increasing levels of soybean meal in the 10% sucrose and 10% tallow diets. The detailed nutrient and chemical composition of these diets are shown in Table 2.

The fatty acid composition of the 3 diets is also shown in Table 2. The inclusion of stabilised tallow raised the C18:1 level from about 20% in the control diet to 35.7% in the tallow diet while C18:2 decreased from 48.0 to 13.6%. Minor changes occurred in the levels of C14:0, C16:0, C16:1, C18:0 (all of which showed an increase) and C18:3 (which showed a decrease) in the diet. The pre-experimental feeding and management procedures employed for these sows are generally similar to those described by Aherne et al (1974). At the start of the feeding period, sows were kept in individual stalls. All sows were moved into farrowing stalls at Day 109 of gestation.

After parturition, piglets were weighed at first observation (4-12 hr post-partum), ear-notched and their needle-teeth clipped. Piglets were injected (intramuscular) with 2 ml Imposil 200[2] before 3 days of age and all males except purebreds were castrated at 1 week of age. All litters received a well-fortified creep diet from 2 weeks of age. Creep intake was not measured however. Total feed intake from Day 100 until

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[2]Imposil 200 - Iron dextran complex. Fisons (Canada) Ltd. 26 Prince Andrew Place, Don Mills, Ontario. (Contains 200 mg iron in every 2 ml dose).

parturition was recorded and all sows in Phase 2 were weighed at Day 100 and 112 of gestation. Sows were weighed again within 12 hr. after farrowing and finally at the end of the 3-week lactation. Lactating sows at both centers were fed a lactation diet (17% crude protein) on a scale which ensured that, at 10 days post-partum, each sow was receiving 5.5 kg of feed daily until weaning. Total number of pigs born alive, born dead, number weaned, gestation length and piglet weights at birth, 1, 2 and 3 weeks of age were recorded during the experiment.

2. Colostrum Samples: Colostrum samples were obtained at less than 18 hr. post-partum. Colostrum let-down was induced by the injection of 30 IU of oxytocin into an ear-vein. Samples were drawn from each functional teat, bulked and preserved with mercuric chloride. Samples were kept frozen (0°C) until analysed. Colostrum was collected from 4 sows per treatment.

3. Chemical Analyses:

(a) Samples of the 3 diets used in this experiment were ground and analysed for crude protein, ash and ether extract by AOAC (1970) methods. Gross energy content was determined in a Parr Oxygen Bomb Calorimeter[3] equipped with a Brown Electronik Recorder[4]. Colostrum samples were analysed for crude protein (N x 6.38), total solids and gross energy

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[3]Parr Instrument Co., Moline, Illinois.
[4]Minneapolis - Honeywell Regulator Co., Philadelphia, Pennsylvania.

by (1) Kjeldahl method (2) freeze-drying and (3) bomb calorimetry respectively. Colostrum was analysed for total lipid content as described by AOAC (1970).

(b) Fatty Acid Pattern of Colostrum:

Fat was extracted from the colostrum by a modification of the method of Roese-Gottlieb (AOAC, 1970). This involved a thorough mixing of 10 ml colostrum sample with 1.25 ml concentrated ammonium hydroxide. Ten ml of ethanol was next added and mixed well. After adding 20 ml petroleum ether and shaking for 1 minute, the top layer was removed and 10 ml of this transferred into a screw-cap culture tube. The solvent was removed under nitrogen in a warm water bath and the fat methylated,as described in Appendix 1. The methyl esters of the fatty acids were used for gas chromatography. Separation of the methyl esters was achieved on a 366 cm long and 2 mm inner diameter glass column packed with 10% CP on 100-120 mesh Chromosorb W-Acid washed. The following isothermal conditions prevailed: column temperature: 220°C, inlet and detector (Flame ionisation detector) temperature: 250°C. The flow rates of nitrogen, hydrogen and air were 20 ml/min , 40 ml/min and 1.2 standard cubic foot/hr (S.C.F.H.) respectively.

(c). Fatty Acid Pattern in Feed Samples:

Well-mixed, ground feed samples were hydrolysed and saponified to obtain extracts for methylation. The procedure adopted is described in Appendix 2.

STATISTICAL ANALYSES[1]

Data were analysed using analyses of variance. Analyses of variance involving equal numbers of observations were analysed according to procedures given by Steel and Torrie (1960).

Analyses of variance involving unequal numbers of observations were computed to adjust for all effects (Yates, 1934; Harvey, 1960 and Overall and Klett, 1972). Actual calculations were made using regression programs coded with dummy variables; variables were coded as shown in Overall and Klett (1972)

Multiple comparison of means were made using the Newman-Kuels procedure (Steel and Torrie,1960). Comparison within the interaction tables were made using the Tukey HSD procedure as outlined by Cicchetti (1972).

The following symbols were used to denote tests of significance:

Symbol	Meaning
*	Means are significantly different at $P<0.05$.
**	Means are significantly different at $P<0.01$.
a,b,c,d,e	Means bearing the same letter or no letters are not significantly different at $P<0.05$.
SEM	Standard error of the means.
NS	Means are not significantly different at $P<0.05$.

[1]Refers to analyses carried out in all the experiments.

RESULTS AND DISCUSSION-EXPERIMENT 1

SOW AND LITTER PERFORMANCE

One sow from the C-H treatment was removed from the experiment (Rep. 2) because she suffered from uterine prolapse after farrowing. All data for this sow were discarded. The treatment x replicate interactions were not significant, indicating that the results at both centers were similar. Therefore, the results for both replicates were pooled and are reported thus.

The reporductive performance of the sows on the 4 gestation treatments are shown in Table 3. Total feed intake, feed intake from Day 100 to Day 112 of gestation and average daily feed intake from Day 100 to parturition were significantly different ($P<0.01$) between treatments. As expected, sucrose inclusion led to a greater feed intake ($P<0.05$) while the inclusion of tallow led to a reduction (NS) in feed intake relative to that of sows fed the control diet ad libitum.

The greater energy density (Table 2) of the 10% tallow diet was probably responsible for the reduction in feed intake relative to that on the other ad libitum fed diets. However, daily caloric intake on the basis of the determined gross energy content were 7.6, 16.0, 16.9 and 16.4 Mcal for the C-L, C-H, SU and TA sows respectively, suggesting that sows do tend to eat to satisfy their energy requirements. On the other hand, the corresponding values when the calculated digestible energy (DE) contents were used were 6.1, 12.8, 13.4 and 13.9 Mcal per day, which indicates that the high energy TA diet led to a slight increase in DE intake.

TABLE 3

FEED INTAKE AND WEIGHT CHANGES AND LITTER PERFORMANCE AND SURVIVAL[1]
(FROM DAY 100 OF GESTATION)

Treatment	C-L	C-H	SU	TA	SEM	Significance
Total Number of Sows	21	19	21	20		
Total Feed Intake, kg	30.3^{a}	61.2^{b}	69.5^{c}	57.0^{b}	2.38	**
Daily Feed Intake, kg	2.0^{a}	4.2^{b}	4.6^{c}	3.8^{b}	0.16	**
Day 100-112 Feed Intake, kg	24.0^{a}	50.6^{bc}	58.1^{c}	42.1^{b}	3.02	**
Gestation Length, days	114.7	114.9	115.2	115.3	0.41	NS
Liveweight (kg):						
Day 100 (Initial)	187.6^{a}	198.8^{b}	197.0^{ab}	194.2^{ab}	2.31	*
Day 112	201.9^{a}	223.1^{b}	223.4^{b}	218.0^{b}	2.31	*
Day 1 Post-partum	184.4^{a}	199.3^{b}	202.4^{b}	203.1^{b}	2.31	*
Day 21 Post-partum	168.9^{a}	182.0^{b}	182.3^{b}	183.5^{b}	2.31	*
Weight gain/loss (kg)						
Day 100-112	$+14.3^{a}$	$+24.3^{b}$	$+26.4^{b}$	$+24.7^{b}$	3.33[2]	*
21-day Lactation	-15.5	-17.3	-20.1	-19.6	3.33[2]	NS
Number born/litter	11.5	11.7	10.4	11.0	0.57	NS
Number born alive/litter	10.7	10.5	9.3	10.3	0.54	NS
Stillbirth, %/litter	7.6	8.5	9.7	6.6	1.71	NS
Number weaned/litter	9.6	9.5	8.4	9.4	0.43	NS
Weaned, %/litter[3]	90.1	90.2	90.4	91.4	2.96	NS
Birth weight, kg	1.34	1.43	1.45	1.36	0.05	NS
1 week weight, kg	2.34	2.35	2.50	2.49	0.05	NS
2 week weight, kg	3.64^{a}	3.66^{a}	4.03^{b}	3.96^{b}	0.05	*
3 week weight, kg	4.96^{a}	4.95^{a}	5.41^{b}	5.19^{c}	0.05	*

[1]The data on (1) Day 100-112 feed intake and (2) weight changes refer to the 41 sows in the 2nd replicate of the experiment.
[2]Standard error of the difference.
[3]As a % of live born pigs.

The mean gestation lengths for the 4 treatments were not significantly different even though there was a slight trend towards an increase with the higher feeding levels. The liveweights of the sows appeared to have been influenced significantly ($P<0.05$) by the feeding treatments at Day 112 of gestation but there was an initial weight effect since sows allotted to the C-L treatment had a significantly ($P<0.05$) lower mean 100-day weight when compared with the C-H group of sows. To determine if there was in fact a treatment effect, orthogonal comparisons, which involved a comparison of the mean weight gain of a particular treatment with those of the other treatments (Steel and Torrie, 1960) were conducted. These showed that the weight gained by the ad libitum groups were similar to each other but were significantly different ($P<0.05$) from the gain of the control group.

All sows were fed the same diet and in similar amounts during the lactation period. The significant differences obtained in the sow weights at weaning were not treatment related, however, because orthogonal comparisons showed that the weight losses for the 4 treatments were not significantly different. Sows that ate the most feed during late gestation gained the most weight during late gestation and also lost the most weight during the 3-week lactation. The pattern of weight changes observed here is similar to those previously

reported by Mayrose et al (1966); O'Grady (1967); Baker et al (1969); Elsley et al (1969); Vermedahl et al (1969); Lodge (1972) and Buitrago et al (1974b). In the 3 experimental treatments i.e. C-H, SU and TA the weight gained from Day 100 to 112 was greater than the weight loss during the lactation period but this was not true for the C-L group of sows. Thus it would seem that though sows which gain the most weight in gestation also lose more weight during lactation, they may still weigh more at the end of lactation than a more conventionally-fed group. It is worth noting, however, that Lodge (1972) has indicated that reproductive performance was optimal when a pregnant sow was fed to gain 22.7 kg body weight during gestation over and above the weight of the litter. He also indicated that feed was utilised most efficiently when sows were fed restricted feed levels in gestation, followed by high levels of feed in lactation.

Litter sizes for the 4 treatments were satisfactory as were the number born alive and number weaned. Feeding sows ad libitum before parturition did not appear to influence the incidence of agalactia and other related sow reproductive problems. There were no significant differences in total number of pigs born, born alive, percent stillbirth and percent weaned. Percent stillbirth was greatest for the sows that were fed the 10% sucrose diet and lowest for those fed the 10% tallow diet. The former group, it should be mentioned, also recorded the greatest feed intake and even though they had the smallest value for number of pigs weaned

per litter, this would seem to be related to their smaller litter size at birth. The values for numbers weaned as a percent of numbers born alive were not significantly different. Percent mortality (including stillborn pigs) was 16.5, 18.8, 19.2 and 14.6 for the C-L, C-H, SU and TA treatments respectively and followed the same trend as was observed for the percent stillborn pigs. Seerley et al (1974) have reported that corn oil in a late gestation diet had a positive influence on survival rate of piglets to weaning and attributed this to the fact that a higher percent of those under 1.0 kg in the corn oil treatment survived when compared to a corn starch group. The results obtained here, though not significant, support these observations and also indicates that fat or oil diets may somehow reduce the stillbirth rate.

There was no significant improvement in the birth weight of the piglets as a result of the increased nutrient intake in late gestation. The greatest mean birth weight was from the SU group and the lowest from the C-L group but these differences were not significant ($P<0.05$). Significant increases in birth weights with increase in feed intake have been reported in the literature (Lodge, 1972) but these have generally been studies to determine the effects of increasing nutrient intake from sub-optimal levels to adequate levels. Though responses in birth weight to increased levels of feed or nutrient intake have been observed in several studies; the increased birth weights have not always been significantly different from that of pigs fed recommended feed levels. In this experiment, the addition of 10% stabilised tallow to a

diet fed ad libitum did not improve birth weight over and above that obtained by the feeding of the control diet ad libitum. Friend (1974) has found that piglets from sows fed a corn starch diet were significantly ($P<0.01$) heavier at birth than those from sows fed corn oil. Seerley et al (1974) have not found any such difference.

Several researchers (Bowland 1964; Lodge et al, 1966a,b; O'Grady 1967; Baker et al, 1969; Elsley et al, 1969; and Vermedahl et al, 1969) have observed that piglets with higher birth weights have higher weaning weights. In this experiment the SU piglets which had the highest birth weight also had the highest weaning weight and this was significantly different from the weaning weights of the C-L, C-H and TA piglets. Both Friend (1974) and Seerley et al (1974) have reported a higher 3-week weight for piglets from sows fed corn oil in late gestation-lactation and late gestation respectively. The former also observed a higher creep feed intake by piglets from sows fed corn starch allowing them to gain more weight than the corn oil piglets by 5 weeks of age. Creep feed intake was not measured in this experiment and thus its effect was not determined. In previous studies (Okai et al, 1976), however, it has been shown that creep feed intake did not have a significant effect on the weaning weights of piglets weaned at 3 weeks of age.

FATTY ACID AND PROXIMATE COMPOSITION OF COLOSTRUM (TABLE 4)

The gross composition of colostrum samples from sows on all 4 treatments is shown in Table 4. None of the components, i.e. total solids, crude protein, ash, fat and gross energy,

TABLE 4

FATTY ACID AND PROXIMATE COMPOSITION OF COLOSTRUM[1]

Treatments	C-L	C-H	SU	TA	SEM	Significance
FATTY ACID (% OF TOTAL FATTY ACIDS)						
C14:0	1.9	1.8	2.2	2.3	0.21	NS
C15:0	0.2	0.2	0.3	0.3	0.05	NS
C16:0	22.4^{a}	25.6^{b}	25.3^{b}	22.4^{a}	0.62	**
C16:1	6.6	5.2	6.4	6.8	0.52	NS
C18:0	5.8	6.5	5.7	6.2	0.59	NS
C18:1	42.8^{bc}	38.4^{a}	38.8^{ab}	43.6^{c}	1.11	**
C18:2	14.8	16.9	15.9	12.3	1.26	NS
C18:3	1.2	1.4	1.2	1.1	0.11	NS
C20:4	1.0	1.0	0.9	0.9	0.09	NS
Others[2]	3.3^{a}	3.0^{a}	3.3^{a}	4.2^{b}	0.24	*
PROXIMATE						
Total Solids, %	26.0	30.5	25.3	24.2	1.76	NS
Fat, %	6.5	7.9	6.2	7.1	1.79	NS
Ash, %	0.8	0.8	0.8	0.8	0.05	NS
Crude Protein, %	10.6	10.6	10.5	9.5	1.14	NS
Gross Energy, kcal/kg	1501.9	1726.7	1413.7	1345.8	118.50	NS

[1]Four colostrum samples per treatment.

[2]"Others" include margaric and arachidic acid.

was significantly affected by the treatments imposed in late gestation, suggesting that more than adequate feed intake may not lead to changes in colostrum composition. The values reported for total solids, crude protein, ash and fat are all within the ranges found by von Neuhaus (1961) and generally agree with the more recent studies of Miller et al (1971b) and Fahmy (1972). Fahmy (1972) and Siers et al (1976a) have reported energy contents of 1.6 and 1.7 kcal/g respectively and, in this study, the values recorded ranged from 1.3 to 1.7 kcal/g. The colostrum from sows fed the TA diet had a slightly lower crude protein content than those of sows from the C-L, C-H and SU treatments. There was a slightly higher fat content in the colostrum from sows fed the C-H and 10% TA diets. However if percent fat is expressed as a percent of the total solids in the colostrum, the values obtained are 25.0, 25.9, 24.5 and 29.3% for the C-L, C-H, SU and TA treatments respectively. These results suggest that the TA treatment did increase the fat content of the colostrum. In spite of this higher fat content, the colostrum from the 10% TA group contained the lowest amount of gross energy. According to Fahmy (1972), changes in the amount of latent energy of colostrum and milk follow the changes in the dry matter percentage. This is clearly borne out by the data in Table 4.

There is sufficient evidence in the literature (Bowland, 1965; Schuld and Bowland, 1968; Miller et al, 1971b; Friend, 1974; Nielsen and Kruse 1974 and Seerley et al, 1974) to indicate that the amount of fat and other components in colostrum and

milk of sows can be altered through nutrition. However, very few of these studies have considered a situation where more than adequate energy intake has been provided to sows in late gestation. In this experiment it has been demonstrated that such feeding regimens may not have a significant effect on the gross composition of colostrum and may lead in some instances, to only a moderate increase in the fat content. Miller et al (1971b) have observed a slight increase while Friend (1974) and Seerley et al (1974) have reported significant increases in the fat content of colostrum from sows fed corn oil during late gestation. However, Pond and Maner (1974) have mentioned that total fat concentration in sow milk was quite resistant to changes in the level of dietary fat. They observed that increasing the dietary fat level increased the milk fat level slightly. Hughes and Hart (1935) and Perrin (1955) have observed that dramatic changes occur in the gross composition of colostrum between parturition and the first 24-40 hr post-partum; the fact that the samples collected were from few sows and were not obtained at the same time may suggest that there could have been changes in colostrum composition that were not detected.

In Table 4 are shown the fatty acid composition of the colostral fats obtained. Of the fatty acids identified only C16:0 and C18:1 were significantly influenced by the dietary treatments imposed. The lowest levels of C16:0 were from the C-L and TA sows' colostral fat and these were significantly different ($P<0.05$) from the levels for the C-H and SU colostral

fat. This trend was virtually reversed for the C18:1 contents of the colostra from the 4 treatments. The rather high C18:1 content of the colostrum of the C-L group was unexpected in view of the lower levels found in the C-H and SU groups, but it should be mentioned that the levels reported for C18:1 and for the other identified fatty acids for this treatment were generally similar to those reported in the literature (deMan and Bowland 1963; Bowland 1965; Stinson et al, 1967; Schuld and Bowland 1968 and Miller et al, 1971b) and agree favourably with the backfat fatty acid composition determined by some of these authors. The 10% tallow diet given in late gestation did not increase the C18:1 content of colostrum to any significant ($P<0.05$) extent when compared to the value for the C-L group. Miller et al (1971b), Friend (1974) and Seerley et al (1974) have all reported significant increases in the C18:2 content of colostrum from sows fed corn oil in late gestation. The absence of a value significantly greater than that for the C-L group is rather difficult to explain in view of the observations made by deMan and Bowland (1963) that the milk fat from sows receiving a high fat (15% tallow) diet contained 13.3% more C18:1, 7.7% less C16:0, 3.7% less C18:2 and 2.8% less C16:1 than the milk fat from the sows fed a standard diet. The diets received by the C-L, C-H and SU sows were high in C18:2 and this may explain the higher levels of this fatty acid in these treatments; however, even though they were higher than the value for TA colostral fat the differences were not significant. Acids

listed under "Others" will include margaric acid and arachidic acids and the significantly higher level of these in the TA colostrum is most probably related to their higher content in the tallow diet.

SUMMARY - EXPERIMENT 1

The experiment described above was of a short-term nature and was designed to study sow and litter performance after a period of ad libitum feeding. Both total feed intake (Day 100 of gestation until parturition) and daily feed intake were doubled when compared to the control group's intake. The addition of stabilised tallow reduced feed intake to some extent while sugar increased it when compared to the C-H group's intake. The effects of liberal feeding on sow weight gains were quite considerable while the effects on birth weight were minimal, judging from the lack of a significant treatment effect.

This experiment has, shown however, that even with relatively short-term feeding of excess nutrients, quite similar birth weights can be expected but weaning weights may be different depending on the source of added energy, with sucrose and tallow proving better than a grain source. In this experiment, the addition of tallow appeared to have had a positive effect on piglet weight gain especially in the first week post-partum for they weighed as much as the SU piglets which had the largest birth weight. Similar effects have been reported in the literature for corn oil diets. There was a trend towards better survival with the tallow diet; this was reflected in both the % stillbirth and % weaned/litter. However, it is important that the economics of tallow inclusion be studied carefully in view of its high cost.

There were no major changes in the gross composition of colostrum with short-term ad libitum feeding. Trends were observed towards higher fat level with the C-H and TA groups and the lowest level with the SU group. Perhaps some of the glucose from the breakdown of sugar is being transferred across the placenta for glycogen deposition in the piglet. It would seem necessary to determine the gross carcass composition and also the glycogen content of piglet carcasses at birth and in the neonatal period to resolve this question.

Only 3 of the 9 major fatty acids shown in Table 4 exhibited significant changes when compared to the results for the control group. C16:0 decreased in the colostrum of the C-L and TA treatments and was high in the C-H and SU treatments. On the other hand, C18:1 decreased significantly in the C-H and SU colostra and was high in the C-L and TA groups. The high C18:1 level in the C-L is not explained by excessive body fat breakdown since the lactation weight losses were not significantly greater. In fact, weight loss in lactation was lowest for the C-L sows.

EXPERIMENT 2

General Comments:

The previous experiment showed some significant effects of ad libitum feeding of 3 diets in late gestation on sow and litter performance to weaning. There were general trends toward increased in birth weight and in survival from birth to weaning. In this, the second experiment, an attempt was made to determine the carcass characteristics of piglets from sows given the same dietary treatments from Day 100 of gestation until parturition. It was considered necessary to determine the sows and piglets sera constituents to observe changes, if any, in blood profiles.

A total of 38 sows that were not involved in the first experiment were used in this experiment; 20 of these (5 per treatment) were used in the first part of the study where sow blood constituents were studied at 3 intervals before parturition. The proximate and fatty acid composition of the piglet carcasses at birth and during the neonatal period were determined. To provide additional data on glycogen content, the remaining 18 sows were similarly fed (part 2) and their piglets serially slaughtered at birth, 24 and 48 hr postpartum. This wa intended to show if sow feed intake had an effect on the glycogen content of liver and muscle tissue of the newborn and neonatal pigs.

The muscle selected was the L. dorsi. No attempt was made to determine the total mass of either the liver or the L.dorsi. This was to avoid possible losses in the glycogen

content in the course of preparing samples for weighing. The blood serum profiles of the piglets were also determined. These studies were primarily designed to determine treatment effects of sow nutrition in late gestation on the body composition and liver glycogen content of newborn and neonatal pigs and to monitor changes in sows after a test period. However, the effects of age per se will be mentioned where necessary.

EXPERIMENT 2. PART I. CARCASS PROXIMATE AND FATTY ACID COMPOSITION

Experimental Procedures

1. Animals and Diets

A total of 20 crossbred sows, distributed equally to the previously described (Table 2) C-L, C-H, SU and TA treatments, were used in this experiment. The feeding period was from Day 100 of gestation until farrowing. Sows were weighed at the start (Day 100), prior to parturition (Day 112) and after parturition (48 hr post-partum). Sows were kept in farrowing stalls bedded with wood shavings. Farrowings were attended to obtain randomly selected piglets for slaughter at birth. All newborn pigs were weighed after the umbilical cord had been cut to a 4 cm length. The surviving piglets were killed at either 24 or 48 hr of age after they had been weighed. A minimum of 8 piglets were killed at each of the three slaughter periods for each of the 4 treatments. All sows received 2.0 kg per day of the control (C-L)diet on the first and second days of lactation.

2. Collection of Samples

i. A minimum of 3 sows per treatment were bled by anterior vena cava puncture (Carle and Dewhirst, 1942) at Day 100, 102 and 108 of gestation. Samples were allowed to stand for 10 minutes and then centrifuged at 2500 rpm. (1.1 g) to obtain the serum. Serum samples were stored at - 30°C after they had been frozen at 0°C.

ii. Blood samples were obtained from all piglets slaughtered at birth. These were collected in beakers containing sodium fluoride (10 mg/10 ml blood) and 14 mg ethylene diamine tetracetate (EDTA). The plasma obtained after centrifuging each sample at 2500 rpm (1.1 g) was used for plasma lactic acid determination. Only the plasma samples of piglets less than 9 in the farrowing order were analysed because it is recognised that lactate levels were higher in pigs born later in the litter (Pettigrew et al, 1971). Samples were stored frozen until analyzed.

iii. Carcasses were weighed after exsamguination and were cut open and the digestive and urinary tracts were removed. After obtaining "empty" body weights, the carcasses were sealed in polyethylene bags and frozen at 0°C.

3. Preparation of Carcasses for Analyses

Carcasses were partially thawed and ground once using a Globe Hamburger Mill (Model 6420)[1]. The carcasses were freeze-dried[2] to a constant weight (72-96 hr) at a shelf temperature of 37.8°C. The samples were then finely ground using a Wiley Mill[3] (no. 1), put into polyethylene bags, sealed and stored at 1-2°C until analysed.

4. Chemical Analyses

i. Duplicate samples were analysed for final dry matter, total Kjeldahl nitrogen and ash content by AOAC (1970) methods.

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[1] Simpson Computing Scale Co. Incorporated, Louisville, Kentucky, U.S.A.

[2] Repp Sublimator, Model SRC 42, Division of Virtis Co. Inc., Gardiner, New York, U.S.A.

[3] Arthur H. Thomas Company, Philadelphia, Pa., U.S.A.

Gross energy was determined with an adiabatic oxygen bomb calorimeter as described in Experiment 1.

ii. Total Carcass Lipids and Fatty Acid Pattern in Carcasses

Two g of the finely ground carcass was homogenized[4] in 20-40 ml of a 2:1 Chloroform: methanol mixture for 5 minutes. The homogenate was filtered (with suction through a funnel) with filter paper and the extraction repeated with an extra 25 ml of the chloroform:methanol mixture. The homogenizing vessel was surrounded by ice.

The combined filtrate was transferred to an Erlenmeyer flask and 20% by volume of 0.05% calcium chloride was added and mixed. After standing overnight, the total volume of the chloroform (bottom layer) was recorded and a 25 ml aliquot was added to a dry, weighed beaker. The chloroform was evaporated on a steam bath and the beaker was heated in an oven at 100°C for 40 minutes. After cooling to room temperature in a dessicator, the beaker was weighed. Per cent total lipid was determined as follows:

$$\% \text{ total lipid} = \frac{\text{Total ml of Chloroform layer} \times \text{weight of lipid in aliquot}}{\text{weight of sample} \times 25 \text{ ml}} \times 100$$

The fatty acid pattern of carcasses was determined using the chloroform:methanol extract obtained above. The extraction procedure described above was similar to that of Folch et al (1957). The steps required before samples can be analyzed has been described in Appendix 1. This involved the methylation

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[4] Virtis "23" homogenizer. The Virtis Co., Yonkers, New York, U.S.A.

of the fatty acids present and their purification using thin layer chromatography. The individual fatty acids in the esters were separated by gas chromatography[5] at 220°C with a 366 cm long and 2 mm inner diameter glass column packed with 10% SP 2340 on 100-120 mesh Chromosorb W-Acid Washed. Column temperature was 190-225°C at 3 °/min while the inlet and detector (Flame ionisation detector) temperatures were 255° and 255°C respectively. The nitrogen and hydrogen flow rates were 20 and 40 ml/min while the air-flow rate was 1.2 S.C.F.H. The individual fatty acids were identified by comparing their retention times with the retention times of pure fatty acid methyl esters.

Method of Calculation

Peak areas were obtained with the aid of a Vidar 6300 digital integrator[6] attached to a recorder[7]. % composition of each fatty acid was estimated by quantitating the area of each fatty acid and expressing this as a % of the total fatty acids detected.

iii. Plasma Lactic Acid Determination

A Sigma Reagent Kit[8] was used. The plasma was deproteinised with cold 8% perchloric acid and centrifuged twice to obtain a clear supernatant. This supernatant was incubated

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[5]Bendix Gas Chromatograph-2500. Bendix International Operations, 605, Third Avenue, New York, N.Y., 10016 U.S.A.
[6]Vidar Autolab, 77 Ortega Avenue, Mountain View, Calif. 94040 U.S.A.
[7]Microcord Model 44. Photovold Corp., 1115 Broadway, New York, 10010 U.S.A.
[8]Sigma Tech. Bulletin No. 826-UV (1975) Sigma Chemical Company. P.O. Box 14508, Saint Louis, Miss., 63178 U.S.A.

with nicotinamide adenine dinucleotide (NAD) and lactic dehydrogenase (LDH). The reactions that occurs is as follows:

$$\text{NAD} + \text{Lactic Acid} \xrightarrow{\text{LDH}} \text{Pyruvic Acid} + \text{NADH}$$

The increased absorbance at 340 nm due to NADH formation becomes a measure of the lactic acid originally present. A summary of the analytical procedure is shown in Appendix 3. Only the plasma from newborn pigs was analysed for lactic acid content and the procedure was modified slightly to suit high concentrations of lactic acid (Sigma Tech. Bull. p. 11).

5. Sow Serum Profile

Serum samples were analysed for calcium, inorganic phosphorus, alkaline phosphatase, uric acid, lactic dehydrogenase, serum glutamic oxaloacetic transaminase, glucose, urea nitrogen, cholesterol, albumin, bilirubin and total protein by a commercial laboratory.[9] This laboratory uses a Technicon SMA 12/60 Autoanalyzer[10]. The procedures involved have been described by Perrin (1975).

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[9]Dr. S. Hanson and Associates, Medical Laboratory, Edmonton, Alberta.

[10]Technicon Instruments Corporation, Tarrytown, New York.

RESULTS AND DISCUSSION (EXPERIMENT 2 PART 1)

SOW AND LITTER PERFORMANCE

The feed intake and reproductive performance of the 20 sows involved in the first part of the experiment are shown in Table 5. Sow weights were not significantly different ($P<0.05$) between treatments at either Day 100 or Day 112 of gestation. This could be attributed to considerable variation in initial and final weights of individual sows within treatments. The differences between the mean weights gained during this period were quite similar for the 3 ad libitum groups but these were significantly ($P<0.01$) greater than the weight gained by the control group during this period. The highly significant ($P<0.01$) differences between the total and daily feed intake of the C-H, SU and TA groups when these were compared to the control group were probably responsible for the higher weight gains. Again there was a trend towards a reduction in feed intake with the TA diet and an increase with the SU diet when these are compared to the C-H treatment. The birth, 24- and 48-hr weights of piglets from the 4 treatments did not appear to have been influenced by the late gestation feed intake. The differences in the weights recorded were quite small and not significant. This, in effect, confirms the results reported in experiment 1.

Blood lactic acid levels in newborn pigs were determined to provide an indication of peripartum stress. As shown in Table 5; the values recorded were not significantly different and no definite trend was observed. It may be suggested that the short-term availability of excess nutrients and the con-

TABLE 5

SOW AND PIGLET WEIGHTS, SOW FEED INTAKE AND PIGLET LACTIC ACID LEVEL AT BIRTH
(DAY 100 OF GESTATION UNTIL PARTURITION)

Treatment	C-L	C-H	SU	TA	SEM	Significance
Total No. of Sows	5	5	5	5		
Day 100 Weight, kg[1]	235.9	207.5	224.7	214.5	11.43	NS
Day 112 Weight, kg	239.6	238.1	257.3	246.3	11.22	NS
Weight Gain, (Day 100-112), kg	3.7[a]	30.6[b]	32.6[b]	31.8[b]	4.69	**
Day 2, Post-partum Weight, kg	224.1	216.5	229.5	219.3	10.75	NS
Total Feed Intake, kg	28.8[a]	88.1[b]	94.3[b]	83.6[b]	11.35	**
Daily Feed Intake, kg	2.0[a]	5.5[b]	6.2[b]	5.4[b]	0.66	**
Birth Weight, kg *						
All Pigs+	1.20(63)	1.40(54)	1.26(62)	1.36(57)	0.07	NS
Liveborn Pigs	1.21(59)	1.40(50)	1.26(53)	1.40(50)	0.03	NS
24-Hr. Weight, kg	1.30(20)	1.43(9)	1.30(18)	1.55(16)	0.06	NS
48-Hr. Weight, kg	1.49(21)	1.74(10)	1.49(18)	1.65(17)	0.06	NS
Plasma Lactic Acid level at Birth, mg/100 ml	72.6 (11)	86.8 (8)	68.3 (9)	87.6 (11)	14.99	NS

[1]One sow in treatment C-L was not weighed.
*Number of piglets weighed is shown in parentheses.
+Separate analysis was done for this item.

sequent rise in sow weight gain does not impose stress on piglets during the birth process. This is supported by the fact that even though duration of farrowing was not measured for all sows, it did not appear to have been influenced by the treatments imposed.

BLOOD SERUM GLUCOSE, CHOLESTEROL, TOTAL PROTEIN AND UREA NITROGEN OF PREGNANT SOWS

The values determined are shown in Table 6. In 3 of the 4 treatments, serum glucose level increased with stage of gestation. Only the C-H group did not show this increase. Ruiz et al (1971) and Nachreiner and Ginther (1972a,c) have both reported increases in glucose level with stage of gestation. Neither the treatment nor the stage of gestation effects were significant, however. Ruiz et al (1971) and Nachreiner and Ginther (1971a,c and d) have shown that serum cholesterol levels decreased as parturition became imminent in adequately fed sows. A similar result was obtained in this study with the C-L sows. The high feed intake in the other 3 groups prevented a decline in cholesterol level as gestation advanced. Here there was no significant stage of gestation effect but there was a treatment effect ($P<0.05$) at Day 108, with sows fed the tallow diet having the highest cholesterol level. Aherne et al (1976) have reported that the cholesterol levels in the blood of pigs fed oil-containing diets were significantly ($P<0.01$) higher than those of pigs fed a control diet. The total protein values observed were similar to those reported by Miller et al (1961) and Nachreiner and Ginther (1972a,d) for

TABLE 6

SOW SERUM CONSTITUENTS AT DAY 100, 102 AND 108 OF GESTATION[1]

Treatment	C-L	C-H	SU	TA	SEM	Significance
Constituent						
			DAY 100			
Glucose, mg/100 ml	69.5(4)	88.0(3)	88.0(4)	83.8(5)	5.81	NS
Cholesterol, mg/100 ml	93.3	79.3	73.0	91.4	6.18	NS
Total protein, g/100 ml	7.7	7.9	8.1	7.9	0.23	NS
Urea nitrogen, mg/100 ml	11.3	11.7	13.0	12.8	1.10	NS
Calcium, mg/100 ml	9.4	9.9	9.5	9.6	0.27	NS
Phosphorus, mg/100 ml	5.2	5.4	5.3	5.4	0.20	NS
Bilirubin, mg/100 ml	0.2	0.2	0.2	0.2	0.04	NS
Uric acid, mg/100 ml	0.1	0.1	0.1	0.3	0.12	NS
			DAY 102			
Glucose, mg/100 ml	79.5	86.0	88.0	89.8	6.26	NS
Cholesterol, mg/100 ml	95.0	74.5	67.8	87.2	6.67	NS
Total protein, g/100 ml	7.4	7.6	7.3	7.8	0.25	NS
Urea nitrogen, mg/100 ml	9.8	10.5	10.8	13.6	1.19	NS
Calcium, mg/100 ml	9.5	9.1	9.4	9.1	0.29	NS
Phosphorus, mg/100 ml	5.3	5.2	5.5	5.8	0.22	NS
Bilirubin, mg/100 ml	0.2	0.2	0.2	0.3	0.04	NS
Uric acid, mg/100 ml	0.1	0.1	0.1	0.3	0.13	NS
			DAY 108			
Glucose, mg/100 ml	95.5^{a}	88.7^{ab}	93.5^{ab}	98.2^{b}	5.81	NS
Cholesterol, mg/100 ml	80.0^{a}	100.0^{ab}	89.3^{ab}	115.8^{b}	6.18	*
Total protein, g/100 ml	6.9	7.6	7.4	7.1	0.23	NS
Urea nitrogen, mg/100 ml	7.0	11.7	11.5	12.6	1.10	NS
Calcium, mg/100 ml	8.4	9.7	9.7	9.7	0.27	NS
Phosphorus, mg/100 ml	5.7	6.0	5.9	5.7	0.20	NS
Bilirubin, mg/100 ml	0.2	0.1	0.2	0.2	0.04	NS
Uric acid, mg/100 ml	0.03	0.2	0.3	0.4	0.13	NS

[1]Number of sows sampled is shown in parentheses.

sows in late gestation and as indicated by the latter researchers, they showed a tendency to decline by Day 108 (near term). Thus, while there was no significant treatment effect, there was a significant ($P<0.01$) stage of gestation effect. Blood urea is the end-product of nitrogen metabolism in terrestrial vertebrates (Mahler and Cordes, 1966) and an increase in urea levels indicates an increase in protein catabolism in order to supply carbohydrate intermediates. Ruiz et al (1971) have indicated that serum urea nitrogen levels decreased in the last 2 weeks of gestation. Nachreiner and Ginther (1972a,d) and Atinmo et al (1974a) confirmed this. In this experiment, this trend was only true for the C-L group of sows. In the other treatment groups no definite trends were observed and while the exact significance of this is not clear, it is worth mentioning that Atinmo et al (1974a) have observed a significantly ($P<0.005$) higher urea nitrogen level in a control group of gilts than in a similar group of gilts fed a protein-restricted diet during gestation.

BLOOD SERUM Ca, P, BILIRUBIN AND URIC ACID (TABLE 6)

The studies of Nachreiner and Ginther (1972a,b,c,d) with sows in late gestation showed that the level of Ca remained fairly stable at about 9.3 mg%. In this experiment no major changes were observed; neither treatment nor stage of pregnancy influenced significantly the serum Ca level observed. Phosphorus level ranged from 5.2 to 6.0 mg% during the period of study and was not significantly influenced by either treatment

or stage of pregnancy. Generally the P values recorded were slightly lower than those of Nachreiner and Ginther (1972a,b, c,d). While the level of bilirubin obtained by these workers was about twice that observed in this experiment, it did not appear to be significantly related to either the treatments imposed or the stage of pregnancy. The uric acid levels observed were very low (<1.0) and were similar to those reported by Bowland (1975) and Sarwar and Bowland (1976) for young pigs. The 2 parameters under study, effect of diet and stage of pregnancy did not have a significant effect on serum levels of uric acid.

In conclusion, the results obtained were similar to those cited in the literature. The only significant change was observed with blood cholesterol where the tallow diet and the other 2 diets fed ad libitum led to increases in serum levels. The other parameters measured viz. serum albumin, alkaline phosphatase (AP) lactic dehydrogenase (LDH) and glutamic oxaloacetic transaminase (SGOT) were also not influenced by the treatments or stage of gestation to any significant extent even though AP, LDH and SGOT generally tended to increase by Day 102 and decrease by Day 108 in the 3 ad libitum treatments.

PROXIMATE COMPOSITION OF CARCASSES

The weight of the carcasses both before and after the removal of the alimentary tract and bladder and the proximate composition of the carcasses are shown in Table 7. The treatments imposed on the sows during late gestation did not have a significant ($P<0.05$) effect on any of the criteria described in this table. The age of the piglet significantly ($P<0.01$) influenced its proximate composition, however. Percent water had decreased while crude protein and fat had increased by 48 hr of life ($P<0.01$). Similar observations have been made by several researchers (Manners and McCrea 1963; Brooks and Davis 1969; Seerley and Poole 1974 and Bertsch et al, 1976). The increase in protein and fat are most probably responsible for the increase in carcass dry matter at that age.

The highest carcass and "empty" weights were from the C-H group of piglets but this did not appear to have any major effect on the mean proximate composition of the carcasses in this group. Widdowson (1950) and Pomeroy (1960) have both reported that piglets that were smaller at birth had more water and less crude protein and fat than heavier piglets. The amount of water in the carcasses of the newborn pigs was about 79.4% for all the 4 treatments and is comparable to the findings in the literature (Curtis et al, 1967; Brooks and Davis, 1969; Curtis et al, 1969; Seerley and Poole, 1974; and Seerley et al, 1974).

The increase in carcass crude protein with age in the

TABLE 7

CARCASS PROXIMATE COMPOSITION (BIRTH TO 48 HR OF AGE)[1]

Treatment	C-L	C-H	SU	TA	SEM	Significance
			AT BIRTH			
Carcass Weight,[2] kg	1.11(11)	1.42(11)	1.26(14)	1.18(13)	0.08	NS
Empty Carcass Weight, kg	1.02	1.29	1.16	1.09	0.07	NS
Moisture, %	79.5	79.1	79.7	79.1	0.30	NS
Dry Matter, %	20.5	20.9	20.3	20.9	0.09	NS
Crude Protein (Nx6.25), %	11.7	11.6	10.8	11.3	0.24	NS
Total Lipid, %	1.9	1.9	1.8	2.0	0.18	NS
Ash, %	4.0	4.1	4.1	4.3	0.09	NS
N.F.E.[3]	2.9	3.3	3.6	3.3	0.19	NS
Gross Energy, kcal/kg	909.4	904.7	875.6	909.2	20.66	NS
			24 HR OF AGE			
Carcass Weight, kg	1.18(17)	1.46(9)	1.21(16)	1.47(15)	0.07	NS
Empty Carcass Weight, kg	1.07	1.27	1.09	1.34	0.06	NS
Moisture, %	80.5	80.0	80.5	79.4	0.28	NS
Dry Matter, %	19.5	20.0	19.5	20.6	0.28	NS
Crude Protein, %	12.4	12.3	12.1	12.8	0.23	NS
Total Lipid, %	2.4	2.5	1.9	2.3	0.17	NS
Ash, %	3.8	3.8	4.1	4.1	0.09	NS
N.F.E., %	0.9	1.4	1.4	1.4	0.09	NS
Gross Energy, kcal/kg	900.5	956.6	873.0	958.2	19.67	NS
			48 HR OF AGE			
Carcass Weight, kg	1.40(19)	1.69(10)	1.44(15)	1.55(15)	0.07	NS
Empty Carcass Weight, kg	1.26	1.45	1.30	1.40	0.06	NS
Moisture, %	79.0	78.9	79.9	78.7	0.28	NS
Dry Matter, %	21.0	21.1	20.1	21.3	0.28	NS
Crude Protein, %	12.9	13.3	12.7	13.6	0.22	NS
Total Lipid, %	3.2	3.7	2.9	2.7	0.17	NS
Ash, %	3.6	3.6	3.8	4.1	0.09	NS
N.F.E., %	1.3	0.5	0.7	0.9	0.18	NS
Gross Energy, kcal/kg	1024.2	1052.3	949.2	1017.9	19.23	NS

[1]Number in parentheses is the number of piglets.
[2]Carcass weight refers to the weight of the slaughtered and bled pig, while empty carcass weight is the weight after the removal of the alimentary canal.
[3]N.F.E. means 100 - (% Moisture + % Crude Protein + % Total Lipid + % Ash).

neonatal period has been well documented (Manners and McCrea, 1963; Brooks et al, 1964 and Seerley and Poole, 1974).

In this study and in the literature there was no evidence that adequate or more than adequate nutrient intake by sows in late gestation had any influence on carcass crude protein content. Buitrago et al (1974a) did not observe any significant change in crude protein content of piglets from sows maintained on a low energy regime (2.2 Mcal DE/day) during gestation and neither did Seerley et al (1976) and Bertsch et al (1976).

The percent fat in the carcasses of newborn pigs were 1.9, 1.9, 1.8 and 2.0 for the C-L, C-H, SU and TA groups respectively. The differences between the means were not significant. Sows fed the tallow diet farrowed piglets with the highest fat content. Seerley et al (1974) have made a similar observation with sows maintained on an adequate energy level from a corn oil diet. Since the 3 experimental groups of sows (C-H, SU and TA) were fed ad libitum it was felt that this could increase carcass fat content greatly but this did not happen. Moreover, the slightly greater amount of fat in the TA carcasses at birth was not evident at 48 hr of age; piglets in this group had the lowest fat content at that age. These results are consistent with the results of Experiment 1 in which the TA diet failed to significantly increase the fat content of sow colostrum.

The amount of ash in the carcasses at birth ranged from 4.0 to 4.3% and by 48 hr of age, it had declined to 3.6-4.1%.

Piglets from the TA group contained more ash than the other groups at birth and at 48 hr of age. These levels of ash are similar to those determined by Manners and McCrea (1963), Brooks et al (1964), Wood and Groves (1965), Curtis et al (1967), Friend (1974), Seerley and Poole (1974) and Seerley et al (1974). According to Curtis et al (1969), ash and carbohydrate content in carcasses decreased during the neonatal period. This was confirmed in this study. The levels of nitrogen-free extract (NFE) or carbohydrate recorded at birth follow a pattern similar to those reported for muscle samples in Experiment 2 Part II with piglets from the C-L group of sows showing the lowest glycogen concentration. Results, in this experiment showed there was a rapid decline in carcass carbohydrate content with age. Other studies (Brooks and Davis 1969 and Seerley and Poole 1974) have reported a decline in carbohydrate levels from birth to 48 hr of age.

There is a dearth of information on the energy content of the carcasses of newborn and neonatal pigs and how feeding level during pregnancy affects the gross energy content. In this study carcasses from the C-L, C-H, SU and TA dietary treatments contained 909.4, 904.7, 875.6 and 909.2 kcal/kg respectively at birth. These had increased to 1024.2, 1052.3, 949.2 and 1017.0 kcal/kg by 48 hr of age. The increase with age was most probably due to the increasing dry matter and fat content in the carcasses.

PIGLET CARCASS FATTY ACID COMPOSITION

The stabilised tallow used in this experiment contained 2.6% myristic acid, 1.2% pentadecyclic acid, 24.5% palmitic acid, 2.7% palmitoleic acid, 18.7% stearic acid, 38.7% oleic acid, 6.2% linoleic acid and 1.5% linolenic acid. This was reflected in the tallow diet fed (Table 2) and it was felt that it would lead to a significantly higher oleic (C18:1) acid level in the carcasses of piglets from sows on such treatments as has been reported by Friend (1974), Seerley and Poole (1974) and Seerley et al (1974) for corn oil diets. In this study, about 95% of the fatty acids were identified (Table 8) and the values recorded for each were either comparable to or less than those reported by Brooks and Davis (1969), Friend (1974), Seerley and Poole (1974), Seerley et al (1974) and Bertsch et al (1976).

The short-term ad libitum feed intake by sows in late gestation did not have a significant effect on the carcass fatty acid composition at birth; the only exception was in the level of C16:1 which was significantly lower with the ad libitum groups of sows. The level of C18:1 in the carcasses of the TA piglets at birth was 30.6% but this was lower than the 31.2% observed for the SU piglets. Thus, it could be stated that the fatty acid content of the lipids of newborn pigs did not reflect the fatty acid composition of the sows' diets. It is not certain what may have caused this but it can be speculated that (1) a longer period of feeding may have given different results or (2) there may be differences in

TABLE 8

CARCASS FATTY ACID COMPOSITION (BIRTH TO 48 HR OF AGE)

Fatty Acid (As % Of Total Fatty Acids)	C-L	C-H	SU	TA	SEM	Significance
AT BIRTH						
C14:0	2.2(8)*	2.0(10)	1.9(8)	2.1(8)	0.10	NS
C15:0	1.0	0.9	0.8	0.9	0.08	NS
C16:0	27.5	28.2	27.9	28.1	0.40	NS
C16:1	8.4[b]	7.7[ab]	7.2[a]	7.7[ab]	0.26	*
C18:0	13.3	12.8	13.8	13.4	0.43	NS
C18:1	30.3	30.8	31.2	30.6	1.04	NS
C18:2	4.8	4.8	4.7	5.4	0.35	NS
C18:3	0.8	0.8	0.8	0.7	0.05	NS
C20:3	0.8	0.8	0.7	0.7	0.05	NS
C20:4	5.2	4.9	5.1	4.7	0.40	NS
Others	5.7	6.3	5.9	5.7	0.39	NS
24 HR OF AGE						
C14:0	1.5(8)	2.0(8)	1.8(8)	1.8(8)	0.11	NS
C15:0	0.6	0.7	0.7	0.6	0.09	NS
C16:0	25.1[a]	27.7[b]	27.2[b]	26.8[ab]	0.41	*
C16:1	6.4	7.6	6.5	6.4	0.27	NS
C18:0	10.9	11.4	12.1	11.4	0.44	NS
C18:1	35.6	30.5	30.7	34.2	1.07	NS
C18:2	9.0	7.7	7.8	7.8	0.36	NS
C18:3	1.3	0.9	1.0	1.1	0.05	NS
C20:3	0.6	0.8	0.8	0.7	0.05	NS
C20:4	4.3	5.0	5.6	4.2	0.41	NS
Others	4.7	5.7	5.8	5.0	0.40	NS
48 HR OF AGE						
C14:0	1.4(9)[a]	1.9(10)[b]	1.7(8)[ab]	1.5(8)[ab]	0.10	*
C15:0	0.4	0.6	0.5	0.5	0.08	NS
C16:0	24.8[a]	27.6[b]	27.5[b]	25.8[a]	0.40	*
C16:1	6.4	7.3	7.1	6.4	0.26	NS
C18:0	9.9	8.9	9.7	10.6	0.43	NS
C18:1	37.4	35.9	34.4	36.5	1.02	NS
C18:2	10.7	9.9	10.0	8.8	0.35	NS
C18:3	1.2	1.1	1.1	1.1	0.05	NS
C20:3	0.6	0.5	0.6	0.6	0.05	NS
C20:4	3.6	2.8	3.6	3.9	0.40	NS
Others	3.6	3.5	3.8	4.3	0.39	NS

*Number of piglets is shown in parentheses.

the rates of transfer of various fatty acids across the placental barrier.

Overall, the proportions of myristic, pentadecyclic, palmitic, palmitoleic, stearic and the 2 unsaturated forms of arachidic acid decreased with age while oleic, linoleic and linolenic acid increased with age. These changes were all significant ($P<0.01$) but only led to a significant ($P<0.05$) age x treatment interaction with respect to myristic, palmitic and palmitoleic acid. The sum of the saturated fatty acids identified were 43.9, 43.9, 44.4 and 44.5% for the C-L, C-H, SU and TA treatments respectively at birth while the corresponding values for the unsaturated fatty acids at birth were 50.2, 49.7, 49.7 and 49.9%. Thus, the dietary manipulations imposed on the sows did not seem to have had any major effect on the proportions of saturated and unsaturated fatty acids in the piglet carcasses at birth.

In the literature surveyed it was established (deMan and Bowland, 1963) that the fatty acids pattern in colostrum was similar to that of the backfat of sows and mature pigs. On comparing the colostrum pattern to that of the newborn pigs it is apparent that there are considerable differences especially in the levels of C18:1, C16:0, C18:0 and C18:2; that considerable changes occur in order to attain the typical adult pattern which is similar to the pattern in the body fat is shown by the significant age effect mentioned and in Table 9 where the fatty acid composition of the colostrum and newborn and neonatal piglets from the control group have been presented.

TABLE 9

COMPARISON OF THE COLOSTRUM AND CARCASS FATTY ACIDS OF THE CONTROL (C-L) PIGLETS

	Colostrum	Carcass Birth	Carcass 24-Hr	Carcass 48-Hr
Fatty Acids				
14:0	1.9	2.2	1.5	1.4
15:0	0.2	1.0	0.6	0.4
16:0	22.4	27.5	25.1	24.8
16:1	6.6	8.4	6.4	6.4
18:0	5.8	13.3	10.9	9.9
18:1	42.8	30.3	35.6	37.4
18:2	14.8	4.8	9.0	10.7
18:3	1.2	0.8	1.3	1.2
20:3	-	0.8	0.6	0.6
20:4	1.0	5.2	4.3	3.6
Others	3.3	5.7	4.7	3.6

EXPERIMENT 2. PART II. GLYCOGEN LEVELS IN NEWBORN AND NEONATAL PIGS.

Experimental Procedures

1. Animals and Diets

Eighteen crossbred sows ranging in age and weight from 1.5 to 5 years and 130 to 250 kg and mated to crossbred boars were randomly allotted on the basis of weight to the 4 dietary treatments described previously (Expt. 1). The number of sows on the C-L, C-H, SU and TA treatments were 4, 5, 4, 5 respectively. Records were kept of total feed intake but sows were not weighed at Day 112 of gestation and at 2 days post-partum as in the first part of this experiment.

2. Collection of Tissue Samples at Parturition and Post-Partum

All farrowings were attended. Piglets were randomly selected as they were born, dried and weighed after the umbilical cord had been cut to a length of approximately 4 cm. Piglets were mechanically stunned and killed by cervical dislocation and exsanguination. The collected blood was prepared for chemical analyses as described previously for sows' blood. The viscera were quickly exposed by a ventral incision and 1 or 2 liver lobes (depending on the size of the piglet) were put into plastic vials, capped and immersed into liquid nitrogen. The 2 L. dorsi muscles on each side of the midline were next removed and similarly treated. Frozen samples were stored at -30°C until analysed for glycogen concentration. All piglets not killed at birth were dried and

weighed as they were born and at either 24 or 48 hr were killed and samples collected as described for the newborn group. These piglets were weighed before slaughter. A minimum of 7 piglets were killed at each time period for each treatment.

3. Chemical Analyses

1. Glycogen Determination

The procedure adopted was similar to that of Stanton and Schwartz (1967). One to 2 g frozen samples were solubilised in hot 30% potassium hydroxide; the released glycogen was precipitated with 95% ethanol and hydrolysed with 1.6 N sulphuric acid. The glucose present was determined enzymatically as described in Appendix 4.

2. Piglet Serum Profile determinations were as described in Experiment 2, Part I.

3. Feed Samples were analysed for crude protein, ash, ether extract and gross energy as described previously. The nutrient composition shown in Table 1 represents the means for all feed samples analysed in the 3 studies.

RESULTS AND DISCUSSION (EXPERIMENT 2 PART II)

Sow and Litter Performance

The feed intake of the sows and the piglet weight data obtained are shown in Table 10. Feed intakes were similar for the 3 ad libitum treatments and these were significantly ($P < 0.01$) different from the feed intake of the control group. Of note is the fact that, in this study, the feed intake of the SU group was not the highest for the 3 ad libitum groups as it had been in the previous experiments.

The differences between the liveweights of all newborn pigs were not significant but the difference between the weights for those born alive were significantly ($P<0.05$) different with the TA piglets having a significantly lower weight than the SU group. The mean liveweights of the piglets slaughtered at 24 hr of age were similar but the weights of those slaughtered at 48 hr of age were significantly different. In this instance however the heaviest pigs were from the C-L treatments and their mean weight was significantly ($P<0.05$) different from the weight of the C-H group but similar to those of the SU and TA piglets. These differences are difficult to interpret especially in the light of the results of Experiment 1 and Experiment 2, Part I, in which the same 4 treatments gave no significant effects.

BLOOD SERUM GLUCOSE, CHOLESTEROL, TOTAL PROTEIN AND UREA NITROGEN

As shown in Table 11, the treatments imposed on the dams in late gestation did not have a significant effect on piglet serum glucose, cholesterol, total protein and urea nitrogen levels. Age of the piglet, on the other hand, had a signifi-

TABLE 10

EXPERIMENT 2 (PART II)

SOW FEED INTAKE (FROM DAY 100 OF GESTATION) AND PIGLET BIRTH WEIGHT[1]

Treatment	C-L	C-H	SU	TA	SEM	Significance
Total Feed Intake, kg	26.0(4)[a]	71.1(5)[b]	68.8(4)[b]	68.6(5)[b]	10.06	**
Daily Feed Intake, kg	2.0[a]	5.3[b]	4.7[b]	4.7[b]	0.57	**
Birth Weight, kg						
All pigs[2]	1.33(40)	1.43(40)	1.39(41)	1.25(61)	0.07	NS
Liveborn pigs	1.29(29)[ab]	1.42(35)[ab]	1.43(30)[b]	1.25(43)[a]	0.04	*
24-Hr Weight, kg	1.30(11)	1.55(10)	1.45(10)	1.32(18)	0.06	NS
48-Hr Weight, kg	1.81(8)[b]	1.45(9)[a]	1.63(9)[ab]	1.50(17)[ab]	0.07	*

[1]Number of piglets or sows studied is shown in parentheses.
[2]Separate analysis of variance was done.

cant ($P<0.01$) effect on serum cholesterol, total protein and urea nitrogen levels. There were no significant age x treatment interactions. Mersmann (1974) has noted that blood glucose is low in the newborn pig (30-60 mg/100 ml) and several researchers (Goodwin 1957; Swiatek et al, 1968; Bengstsson et al, 1969; Gentz et al, 1970; Pettigrew et al, 1971; Mersmann et al, 1972; Stanton et al, 1973, and Seerley et al, 1974) have data showing similarly low values.

However, in this experiment the serum glucose level was high (>100 mg/100 ml) at birth and either decreased or increased slightly by 48 hr of age, with piglets from sows fed the tallow diet in late gestation recording the highest level at that age. High glucose levels at birth have been reported by Curtis et al (1966), Aherne et al (1969b), Tumbleson and Kalish (1972), Buitrago et al (1974a) and Friend (1974). The possible reasons for the differences in observed glucose levels in newborn pigs have been alluded to in the literature review. These included age of pig, state of nutrition and environment of dam and piglet, type of sample and time interval for sampling and analysis. Serum cholesterol levels were low at birth in all groups and while the maternal treatments did not influence the levels, age had a significant ($P<0.01$) effect on cholesterol levels. In all 4 groups, the cholesterol level rose from birth to 48 hr of age and the C-L litters had the lowest level at either 24 or 48 hr of age. The increase in serum cholesterol level with age has also been reported by Tumbleson and Kalish (1972) and Tumbleson and Hutcheson (1976).

TABLE 11

PIGLET SERUM CONSTITUENTS AT BIRTH, 24- AND 48-HR OF AGE[1]

Treatment	C-L	C-H	SU	TA	SEM	Significance
Constituents			AT BIRTH			
Glucose, mg/100 ml	107.0(8)	135.8(13)	106.5(11)	116.0(11)	11.89	NS
Cholesterol, mg/100 ml	50.9	61.0	53.1	40.0	10.73	NS
Total protein, g/100 ml	2.6	2.4	2.6	2.2	0.60	NS
Urea Nitrogen, mg/100 ml	8.1	10.9	10.5	9.6	4.43	NS
Calcium, mg/100 ml	11.5	10.4	10.9	9.7	0.67	NS
Phosphorus, mg/100 ml	6.6	6.3	6.0	5.7	0.48	NS
Bilirubin, mg/100 ml	0.04	0.1	0.1	0.2	0.13	NS
Uric acid, mg/100 ml	0.9	0.6	0.7	0.6	0.10	NS
			24-HR OF AGE			
Glucose, mg/100 ml	112.7(10)	101.1(10)	116.6(10)	115.6(21)	12.06	NS
Cholesterol, mg/100 ml	65.1	78.6	78.6	76.9	10.21	NS
Total protein, g/100 ml	6.6	4.9	6.4	5.4	0.58	NS
Urea nitrogen, mg/100 ml	23.7	16.7	21.9	16.8	4.22	NS
Calcium, mg/100 ml	10.4	9.5	11.1	10.2	0.64	NS
Phosphorus, mg/100 ml	7.6	6.2	6.6	6.6	0.46	NS
Bilirubin, mg/100 ml	0.4	0.4	0.3	0.5	0.12	NS
Uric acid, mg/100 ml	0.6	0.6	0.4	0.4	0.10	NS
			48-HR OF AGE			
Glucose, mg/100 ml	125.8(8)	108.1(9)	115.3(9)	135.0(21)	11.31	NS
Cholesterol, mg/100 ml	89.9	122.9	127.1	127.2	10.88	NS
Total protein, g/100 ml	6.0	5.2	6.2	5.8	0.61	NS
Urea nitrogen, mg/100 ml	29.0	33.6	23.8	18.2	4.49	NS
Calcium, mg/100 ml	10.5	10.6	12.0	12.0	0.68	NS
Phosphorus, mg/100 ml	6.4	5.8	6.2	7.0	0.49	NS
Bilirubin, mg/100 ml	0.2	0.2	0.3	0.6	0.13	NS
Uric acid, mg/100 ml	0.5	0.7	0.5	0.6	0.11	NS

[1]Number of piglets sampled is shown in parentheses.

Serum total protein was low at birth and was quite high by 24 and 48 hr of age. The increase was significant ($P<0.01$) in all treatment groups. Similar results have been reported by McCance and Widdowson (1959a), Miller et al (1961), Ramirez et al (1963), Mersmann et al (1972), Tumbleson and Kalish (1972) and Tumbleson and Hutcheson (1976). As discussed by McCance and Widdowson (1959a) and Tumbleson and Kalish (1972) the intake of colostrum or more specifically gamma-globulin is responsible for the rise in serum total protein.

Very few of the studies to date have determined serum urea nitrogen levels at birth and soon after. In this experiment, age of the piglet had a significant ($P<0.01$) effect on the urea nitrogen level (Table 11). The values shown for newborn pigs were lower than those reported by Tumbleson and Kalish (1972) who had also mentioned that it increased ($P<0.01$) from birth to 24 hr of age and then decreased ($P<0.05$) by 3 days of age. Generally the glucose levels at birth were greater than, while the cholesterol, total protein and serum urea nitrogen were less than, the levels reported for sows near term (Day 108 of gestation). Glucose levels in fetal pigs near term have, however, been found (Aherne et al, 1969b and Randall and L'Ecuyer, 1976) to be lower than the corresponding maternal values.

BLOOD SERUM Ca, P, BILIRUBIN AND URIC ACID (TABLE 11)

There were no significant treatment effects on the serum Ca, P, bilirubin and uric acid levels. Age of the piglet had

a significant ($P<0.05$) effect only on the levels of bilirubin and uric acid. In all groups, uric acid decreased from birth to 24 hr of age but only the piglets from the C-L treatment showed a further decline by 48 hr of age. Serum bilirubin on the other hand, increased from birth to 24 hr of age and in the SU and TA groups, there were further increases by 48 hr of age. Tumbleson and Kalish (1972) have reported slightly higher Ca and bilirubin but lower P levels in newborn pigs; however, the fluctuations observed by these workers in the levels of these constituents during the neonatal period were similar to those recorded in this experiment. Piglets from sows fed the tallow diet in late gestation had the lowest serum Ca, P. and uric acid but the highest bilirubin at birth. Whether this is related to the higher caloric density of this diet is not certain but Aherne et al (1976) have reported that serum Ca. and P. levels might not reflect the considerable differences in the intake of minerals caused by the variation in the caloric density of diets fed to growing pigs. According to Hansard (1965) absorbed minerals pass freely from dam to fetus at all stages of gestation, with quantity and rate increasing progressively with stage of gestation. He did mention, however, that variations in molecular or ionic size, exchange rate, concentration gradient and other factors can influence the rate and quantity of the various minerals transferred across the placental barrier. The Ca, P. and uric acid levels reported were higher than those shown for sows near term while the bilirubin level

was less. Garel and Barlet (1976) have reported that both newborn foals and lambs have higher Ca and P levels than their dams soon after birth. A similar observation for serum Ca has been made by Krukowski and Smith (1976) with newborn rats.

As in the sow blood profile study, the following were also determined in piglet serum samples, viz. AP, LDH, SGOT and serum albumin. Of these, only AP was not significantly influenced by the age of the piglet. The level of albumin increased gradually from birth to 48 hr of age while LDH and SGOT levels increased by 24 hr of age.

GLYCOGEN LEVEL IN THE LIVER AND MUSCLE OF NEWBORN AND NEONATAL PIGS.

The results obtained are shown in Table 12. The treatments imposed on the sows in late gestation had a significant ($P<0.01$) effect on the liver glycogen concentration at birth. The liver glycogen in the C-L group was the highest but it was only significantly different from that of the TA group. Age also had significant ($P<0.01$) effect and both led to a significant age x treatment interaction.

The high liver glycogen level obtained with piglets from the C-L group perhaps indicates that the level of feeding is sufficient for optimal glycogen deposition. Piglets from the TA group of sows had the lowest liver glycogen level at birth suggesting that fat containing diets do not promote glycogen deposition. Seerley et al (1974) have reported a slightly lower liver glycogen level in piglets from sows fed (near term)

TABLE 12

LIVER AND MUSCLE GLYCOGEN LEVELS (mg/g WET WEIGHT) AT BIRTH, 24- AND 48-HR OF AGE

Treatment	C-L	C-H	SU	TA	SEM	Significance
Age						
			LIVER			
Birth[1]	252.5(9)[b]	208.4(13)[ab]	218.6(13)[ab]	170.3(11)[a]	14.48	**
24-Hr	76.3(10)	49.6(9)	54.6(9)	57.1(10)	14.78	NS
48-Hr	52.4(8)	57.7(8)	64.4(8)	79.1(8)	15.44	NS
			L. DORSI			
Birth	167.3(8)	181.9(14)	180.6(10)	184.7(10)	8.29	NS
24-Hr	132.2(9)	148.4(9)	137.4(10)	131.5(17)	8.13	NS
48-Hr	81.1(8)	99.0(9)	118.6(9)	106.4(15)	8.47	NS

[1]Number in parentheses represents the number of piglet sampled.

a diet that contained corn oil. In earlier studies, Curtis et al (1965) and Reedy et al (1966) have failed to increase liver glycogen levels of piglets from sows "loaded" with glucose in late gestation. The values recorded for liver of newborn pigs in all 4 treatments are generally similar to those found by Mersmann and Houk (1971), Mersmann (1971), Mersmann et al (1972) and Seerley et al (1974). In all but one (control group), minimal liver glycogen level appeared to have been reached within 24 hr after birth as suggested by Mersmann (1974). In the control group, the depletion pattern seemed to follow those established by Mersmann and Houk (1971), Mersmann (1971) and Mersmann et al (1972). Friend (1974) has suggested there could be preferential metabolism of dietary carbohydrate for fetal development with dietary fat being used for body storage. This may explain the lower glycogen content of the liver of the piglets from the TA sows.

In the literature cited it has been shown that the type of muscle analysed can influence the results obtained. In this study the L. dorsi was chosen because of easy accessibility and lack of sufficient data on this particular muscle in piglets. It is thus important that the results shown in Table 12 be compared to values recorded in the literature for that particular muscle. Apparently only Curtis et al (1966) and Seerley et al (1974) have determined the glycogen content of the L. dorsi of newborn pigs. The former recorded a value of 71.6 mg/g while the latter reported a concentration of 147 mg/g. In this study the C-L group's piglets contained

an average of 167.3 mg/g while the C-H, SU and TA groups contained 181.9, 180.6 and 184.7 mg/g respectively at birth. The differences between the means were not significant. Perhaps it could be speculated that feed intakes over and above the recommended level may lead to only a slight increase in muscle glycogen.

The age of the piglet had a significant effect ($P<0.01$) on the glycogen concentration in muscle but, unlike liver samples, this change was more evident at 48 hr of age. This agrees with the conclusions drawn by Shelley (1961) and Mersmann (1974) who have reported that in skeletal muscle the rate of decrease of glycogen after birth was less rapid with minimal levels being reached at 36 to 48 hr post-partum. The 48-hr values reported for the C-L, C-H, SU and TA groups were 48.5, 54.4, 65.7 and 57.6% respectively of the values determined at birth and the corresponding figures for the liver samples are 20.8, 27.7, 29.5 and 46.4%.

SUMMARY - EXPERIMENT 2

The data on feed intake of the sows, their weight changes and weights of the newborn pigs obtained in this experiment are generally comparable to those in Experiment 1. Lactic acid levels in the plasma of piglets were high at birth but were not influenced by the feeding treatments imposed in late gestation. None of the piglet blood parameters studied in this experiment (Experiment 2; part II) appeared to have been affected by the treatments. All the significant changes observed were age and not treatment related. However it is worth noting that by 48 hr of age, piglets from the ad libitum groups of sows had the highest cholesterol levels in the blood. Sow blood characteristics were similar between treatments at the start of the test period and the only significant change over the 8-day period was the high level of cholesterol observed with the tallow diet. Owing to the lack of a significant treatment effect on piglet proximate carcass composition, one can only mention trends. Of note, are the slight increase in carcass fat at birth with tallow feeding and the slightly higher NFE values obtained with the C-H, SU and TA groups. The increase in carcass fat mentioned may explain the trend towards higher survival shown by this group in Experiment 1. Moreover, the SU piglets which had the highest NFE value did not have the highest survival rate. As with the colostrum samples, the similarity in the content of C16:0 and C18:1 for the C-L and TA groups was also evident in the carcass samples at 24 and 48 hr of age.

There have been more studies on the glycogen depletion pattern in liver samples than in muscle tissues. In this experiment it has been confirmed that the rate of depletion in muscle is slower than in the liver. However, the muscle studied, i.e. L. dorsi, does not seem to give a good indication of post-natal changes in the carcasses' carbohydrate content for, while the carcass level had declined to about 40.1% of the level at birth by 24 hr of age, the level in the L. dorsi was 76.9% of the level at birth. The importance of specifying the muscle analysed has been discussed by some workers. The present study indicates that in the neonatal period, changes may be occurring in the glycogen content that may not be reflected in the glycogen level of the L. dorsi. The literature surveyed has indicated that the B. femoris may have a depletion pattern more similar to the pattern in the total body.

GENERAL DISCUSSION

Piglet deaths still account for 20-30% of all pigs born and most of these losses occur in the first 72 hr of life. In spite of the fact that swine researchers have been able to overcome some of the inefficiencies in swine production, they have, so far, been singularly unsuccessful in reducing to any significant extent, the high mortality that has been plaguing the swine industry. This is proven by the fact that piglet mortality in the seventies is similar to what it was in the sixties. It is true though that there are some producers who are doing very well in this respect. England (1974) listed certain feeding and management practices that he considered could reduce mortality but the economics of some of these practices can be questioned. The losses of piglets can be related, among other things, to the paucity of body fat in newborn pigs and the rapid depletion of its glycogen reserves.

The studies described in this thesis were undertaken to determine the body reserves of newborn and neonatal pigs, blood constituent changes and the performance to weaning age, of piglets from sows given an excess of nutrients in late gestation. The 4 treatments: control-low, control-high (ad libitum), 10% sucrose diet (ad libitum) and 10% stabilised tallow diet (ad libitum), did not lead to significant differences in most of the reproductive and litter performance parameters studied. The excess nutrient intake led only to a high gestation weight gain and very little improvement in birth weight. What is worth noting here is that even though

previous studies have shown this same result; they have been under situations where high feed or caloric intake has been imposed throughout pregnancy while this study was only for the last 2 weeks of gestation. Moreover, reproductive performance and the sows' ability to nurse their litters did not appear to have been adversely affected by the treatments imposed.

The colostrum samples analysed were too few to permit any firm conclusions. There are however, substantial data on the effects of including fat or oil in the sow's diet on the gross and fatty acid composition of colostrum. The sow's capacity to buffer the fetuses against nutritional deficiencies, also appears to work in the other direction, i.e. when excess nutrient is available. This may, to some extent, explain the lack of response shown in these studies. There was no significant treatment effect in the carcass and colostral fat content with the feeding of tallow to the sows in late gestation. It is unfortunate that the plasma fatty acid levels in the sows were not determined for it has been shown that with either the infusion of or incorporation into the feed of triolein, the composition of the plasma triglyceride of lactating sows was altered towards that of triolein (Witter et al, 1970; Witter and Rook 1970). Moreover, the changes in the fatty acid composition of the plasma were reflected in the composition of milk fat from these sows, indicating a direct transfer of the fatty acids into milk. A study of the plasma fatty acid composition would have indicated whether it has been altered as a result of the tallow

and other ad libitum treatments. The only blood parameter studied that may give an indication of the fat status in the sow's blood was cholesterol which was observed to have increased.

Transport of fatty acids across the placenta can be estimated from the relationship of the maternal to fetal concentrations of fatty acids, the transfer of labelled fatty acids, umbilical blood venous - arterial differences and other techniques. Szabo and Szabo (1974) and Hull (1975) have noted that in most species fatty acids readily cross the placenta into the fetus. However, the sow was not mentioned in these reports and, in the light of the minimal increase observed in the carcass fat content of the newborn pigs from sows fed a tallow diet, one wonders whether the placenta with its high number (6 in sows) of layers or membranes may be acting as a barrier to fatty acid transfer. One should also not discount the possible influence of the placenta as a storage organ for triglyceride and the possibility that the number and capacity of the adipose tissue may be limited, for it is one of the last major body tissues to appear. Finally, Szabo and Szabo (1974) have noted that in animal species having a poor placental free fatty acid transfer eg. the rat adipose tissue comprised only 1% of the body weight of the newborn; perhaps the pig is in this same category.

The last word naturally belongs to glycogen: this study has shown that the maximal level may in fact be obtained with adequate nutrient intake as in the C-L group of sows. Feeding excess nutrients in the form of glucose (whether from starch or

sucrose) to sows in late gestation did not lead to significant increases in liver and skeletal muscle levels at birth. The levels in the livers of the offspring from the ad libitum groups were considerably lower. This may not be attributable to glycogenolysis in the peripartum period in view of the observations that glucose and lactic acid levels in the blood of the newborn pigs were not significantly influenced by the treatment.

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APPENDIX 1

FATTY ACID PATTERN OF TOTAL LIPIDS USING CHLOROFORM:METHANOL EXTRACT

A. METHYLATION

Reagents: i. Methylation reagent
- 35% Boron trifluoride (BF_3) solution.
- 10% Boron trifluoride in methanol (MeOH).
- 20% n-pentane
- 45% methanol

ii. Chloroform-methanol

PROCEDURE:

1. Transfer some of the chloroform:methanol extract to a methylation tube (approx. 100-200 mg fat).
2. Evaporate the solvent under nitrogen in a water bath.
3. Add approx. 10-15 ml of the methylation reagent {35% BF_3 solution (10% BF_3 in MeOH), 20% n-pentane and 45% MeOH}
4. Close with teflon-lined screw cap and heat in boiling water bath for 40-60 minutes. Shake occasionally.
5. Cool the tube to room temperature, open and carefully add approx. 5 ml distilled water and 10 ml n-pentane. Shake briefly.
6. Remove pentane (upper) layer with a Pasteur pipette and store under nitrogen in glass vials with teflon-lined caps.
7. Purify the methyl esters (from no. 6 above) on thin-layer chromatograph plates[1]. Develop the plate in benzene to the top (approx. 1 to 1.5 hr). Identify the methyl esters under short-wave ultra-violet light.
8. Scrape the methyl esters into a funnel and extract with chloroform:methanol (2:1). Store under nitrogen in glass vials.
9. Run gas chromatographs.

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[1] Coated with 0.25 mm Silica gel with fluorescent indicator UV_{254} Macherey-Nagel Co., 516 Doren-WerkstraBe, 6-8 Postfach 307, Germany.

APPENDIX 2

FATTY ACID PATTERN IN FEED SAMPLES

REAGENTS:

4N HCl, 10% HCl
N-pentane
Methanol (MeOH)
40% potassium hydroxide (KOH)
1% sodium chloride solution (NaCl)
BF_4 reagent

PROCEDURE:

1. Hydrolysis

   a. 10 g of well mixed ground sample was weighed into a beaker and 10 ml of acqueous 4N HCl added. Glass beads were also added and the mixture boiled gently for 30 minutes.
   b. The hot hydrolysate was filtered using a filter paper and the residue was washed several times with hot water (pH 6).
   c. The filtrate was discarded; the filter paper was dried overnight in a freeze-drier (37.8°C), transferred into a thimble and lipids were extracted in a Goldfish apparatus with pentane for 4-6 hr.
   d. The solvent was evaporated on a steam bath.

2. Saponification

   a. 50 ml of MeOH, 4 ml KOH and glass beads were added to the lipid extract and boiled under a reflux condenser for 30 minutes with regular shaking.
   b. This was cooled and distilled water (50 ml water/50 ml MeOH) added.
   c. The soap was placed in a separatory funnel, washed thrice with distilled water (10 ml) and 100 ml of pentane added.
   d. After gentle shaking (for good separation), the water fraction was drained into another funnel and washed with 100 ml pentane and 2 drops of NaCl solution.
   e. 10% HCl was added to the water-MeOH fraction (pH 3). Then 100 ml pentane was added and shaken vigorously. After 2 extractions, the pentane phase was retained and the FFA filtered over sodium sulphate into a flask. The pentane was evaporated and the water layer removed.

3. Methylation:

a. 4 ml BF_3 (10% BF_3 in MeOH) was added to the FFA in the flask, covered (Kleenex tissues) and cooked on a steam bath until the specimen changes from "Clear" to "Milky" (4 minutes).
b. The flask was removed, 30 ml of 1% NaCl solution was added to the contents and allowed to cool completely.
c. The methyl ester was extracted twice with 50 ml pentane and evaporated to proper concentrations for gas chromatography.

The conditions that prevailed during gas chromatography were:

Column: (1) glass, 366 cm long and 2 mm inner diameter.
(2) packed with 10% SP 2340 on 100-120 mesh Chromosorb W-Acid washed.
(3) Temperature: 190-225°C at 3°/minute.

Inlet and Flame Detector temperature = 255°C.
Nitrogen and hydrogen flow rates were 20 ml and 40 ml/minute respectively. Air-flow rate was 1.2 S.C.F.H.

APPENDIX 3

PLASMA LACTIC ACID DETERMINATION
(Sigma Technical Bulletin No. 826-UV)

REAGENTS AND MATERIALS:

i. Lactic dehydrogenase enzyme - 1000 units/ml (LDH)
ii. Glycine buffer, contains glycine and hydrazine
iii. Nicotinamide adenine dinucleotide vials - 10 ml/vial (NAD)
iv. 8% (W/W) Perchloric acid
v. Spectrophotometer eg. Beckman - DBG

PROCEDURE:

1. Two ml glycine buffer, 4 ml distilled water and 0.1 ml LDH were pipetted into a NAD vial which was inverted several times to dissolve the NAD.
2. 2.8 ml of this mixture was put into each of 2 test tubes, with one was labelled "Test" and the other "Blank".
3. 0.1 ml of the deproteinised plasma was put into the tube labelled "Test" and 0.1 ml perchloric acid solution was put into the "Blank" tube.
4. 0.1 ml of distilled water was added to each tube to bring the final volume to 3.0 ml.
5. Both tubes were incubated in a water bath at 37°C for 30 minutes.
6. Absorbance of sample (Test) was read at 340 nm (under ultraviolet light) using the Blank as reference

CALCULATION:

Plasma lactic acid (mg/100 ml) = Absorbance reading x 130.3.

APPENDIX 4

GLYCOGEN DETERMINATION

In the procedure described below what is being determined is the number of glucose equivalents per g of tissue.

I. SAMPLE PREPARATION:

A. Reagents and Materials:

30% potassium hydroxide (KOH)
1.6 N sulphuric acid (H_2SO_4)
95% ethanol (EtOH)

B. Procedure

1. Using 2 ml KOH per g of frozen tissue, the weighed tissue sample was boiled in a pyrex tube containing KOH until a solution was formed (approximately 1 hr.).
2. 1.1 to 1.2 volumes of EtOH was added, mixed well and the contents of the tube was heated to the boiling point.
3. The tube was cooled and centrifuged at 3000 rpm for 10 minutes.
4. The mother liquor was decanted and tube drained.
5. The precipitate left in the tube was next heated to expel residual EtOH.
6. 2 volumes of H_2SO_4 (1.6 N) was added to the contents of the tube, making sure that any precipitate on the sides of the tube had been washed with the acid.
7. The tube was next heated with regular shaking in a water bath to hydrolyse the glycogen.
8. The hydrolysate was transferred into a volumetric flask and made up to the mark with distilled, deionised water.

II. GLUCOSE DETERMINATION

The Glucostat Reagent Set supplied by Worthington Biochemical Corporation (So. San Francisco, Calif. 94080 U.S.A.) was used.

A. Reagents and Materials:

Glucostat reagent vial containing glucose oxidase, a buffer and peroxidase.
Chromogen vial containing 3,3'-dimethoxybenzidine dihydrochloride.
Spectrophotometer (absorbance read at wave length of 400-425 nm)
Cuvettes

4.0 N hydrochloric acid (HCl)
2.0% zinc sulphate ($ZnSO_4 . 7H_2O$)
1.4% sodium hydroxide (NaOH)
Stock glucose solution - 1000 mg/100 ml in saturated benzoic acid.
Saturated benzoic acid (0.34 g benzoic acid in 100 ml deionised water).

B. Reagent Preparation: (Semi-Micro Method)

a. Add 30 ml deionised water to a 50-ml graduated cylinder
b. Dissolve the chromogen by injecting 5 ml of deionised water into the chromogen vial. Add to the graduated cylinder.
c. Dissolve the contents of the Glucostat vial with deionised water and add to graduated cylinder.
d. Adjust the final volume to 50 ml with deionised water

C. Assay:

- Deproteinisation

a. Set up series of test tubes. Include one for each unknown, one for a reagent blank and one for each standard*.
b. Add 2.0 ml of deionised water to reagent blank tube and 1.9 ml to the other tubes.
c. Add 0.1 ml of sample (diluted hydrolysate) or standard to respective tubes.
d. Mix and add 1.0 ml NaOH solution.
e. Mix and add 1.0 ml $ZnSO_4$ solution.
f. After mixing, filter or centrifuge.
g. The supernatant is used in the glucose assay.

- Enzymatic Determination of Glucose

a. Set up a series of test tubes. Include one for each unknown, one for a reagent blank and one for each standard.
b. Pipette 2.0 ml of supernatant into respective tubes.
c. At timed intervals, add 2.0 ml Glucostat reagent to each tube and mix. Let stand exactly 10 minutes at room temperature.
d. At the same timed intervals, add one drop of 4N HCl to each tube and mix. Let stand for at least 5 minutes.
e. Read absorbance of solutions at 420 nm; set spectrophotometer at zero with reagent blank.

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*Preparation and Calibration of Standard Curve is done as shown in the table below:

f. Draw a standard curve and read concentrations of unknowns directly from standard curve.

CALCULATION:

Glycogen (mg/g wet tissue) =

$$\frac{\text{total glucose concentration (mg)}}{\text{weight of tissue used}}$$

PREPARATION OF STANDARD SOLUTIONS

Units (mg/100 ml)	100	200	300	400
1000 mg/100 ml stock glucose (ml)	1.0	2.0	3.0	4.0
Deionised water (ml)	9.0	8.0	7.0	6.0

These 10 ml solutions are then deproteinised and assayed with the unknown.